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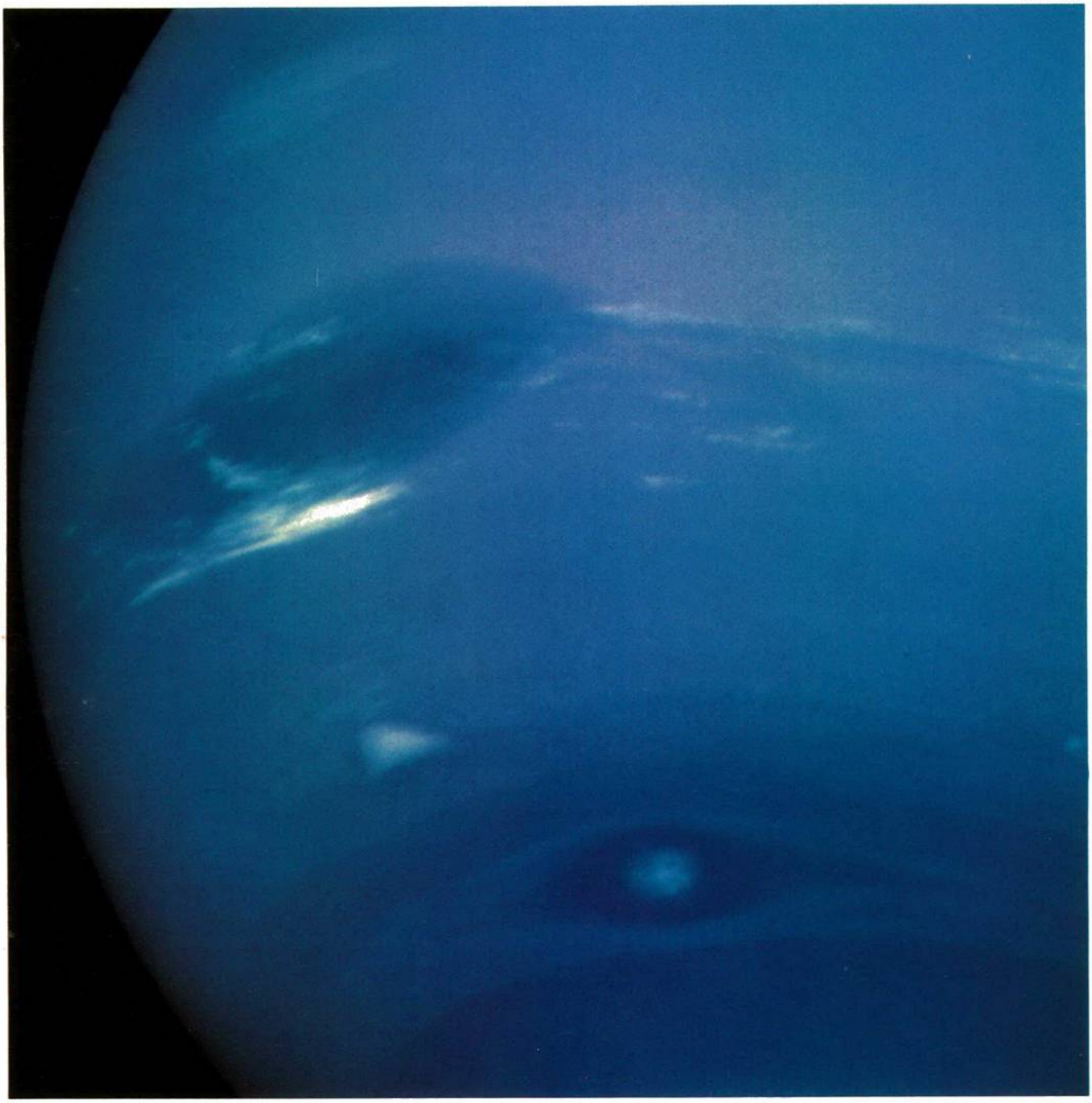

Neptune's Great Dark Spot

Meade 10″ Model 2120/LX6.
Shown with optional Digital Readout System and Superwedge.

Background photo: The Lagoon Nebula (M8). A 20-minute exposure with the Meade 8″ Model 2080/LX6.

Meade® 10″ 2120/LX6: Number One Worldwide.

Now Available with the Meade Superwedge™ for Even More Stability!

The Meade 10″ Wide-Field Model 2120/LX6 is now the World's most popular large-aperture Schmidt-Cassegrain. Meade 10″ 2120 models, in fact, continue to outsell most competing 8″ Schmidt-Cassegrain models!

The 2120/LX6 has achieved this dominant position because it simply offers more value: more features, more accessories, more aperture, more performance for the money. When you buy a Meade 10″ Model 2120/LX6, here's some of what you receive as *standard equipment:*

■ **Fast f/6.3 Schmidt-Cassegrain Optics**—*Individually hand-matched, diffraction-limited optics* that yield wide fields of view and fast photo exposure times not possible with conventional f/10 optics.

■ **Multi-Function Electronic Command Center**—The ECC hand controller puts virtually every telescope function at your fingertips:
☐ *2X Drive Correction Speed* for precise electronic corrections during astrophotography.
☐ *8X Scanning Speed* for rapid electronic centering of the image, or for roving about a sky region at 8X the sidereal speed. Add the optional Declination Motor for dual-axis capability at 2X or 8X speeds.
☐ *Optional Digital Readouts:* Find faint objects in seconds using the Meade Digital Readout System (DRS). The DRS adds easily and quickly to 8″ and 10″ LX6 models and permits precise monitoring of telescope position in RA and Dec, directly from the hand controller.

■ **Advanced-Design Power Panel**—Virtually every modern electronic accessory can be plugged into the telescope's power panel. Accessories including the Meade CAT Computer Aided Telescope system, #1200A Electric Focuser, Digital Readout System, Illuminated Reticle Eyepiece, and more.

■ **A Specifications Listing** that includes 9 x 60mm Polar Illuminated Viewfinder, 2″ Diagonal Mirror (itself a $200 option on competing models), Multi-Coated Optics Group, and Super Plössl 26mm eyepiece.

See your Meade dealer for full details on the 10″ Model 2120/LX6—the telescope that's Number One among serious amateurs worldwide.

■ **NEW! Meade Superwedge**—The equatorial wedge included as standard equipment with the 2120/LX6 is satisfactory for all normal applications of the telescope. Observers who require extreme stability in the most demanding applications may specify the new Superwedge in place of the standard wedge, at additional cost. The Superwedge includes microfine azimuth and elevation controls, and reduces telescope damping time by about 80%.

Add the Superwedge to your Meade 10″ Schmidt-Cassegrain.

The Meade Superwedge is available separately for retrofitting to existing Meade 10″ Schmidt-Cassegrain telescope Models 2120, 2120/LX3, 2120/LX5, and 2120/LX6. Call or write your Meade dealer for details.

Ever expect to see the Great Nebula in Orion (M42) as a glowing blue-green ember? Or resolve the Hercules globular cluster (M13) to the core? Or observe the dust lanes and spiral structure in the Whirlpool Galaxy (M51)? Not just photographically, but **visually.** You can, and can afford to, observe these and countless hundreds of other objects as you've never seen them before, with a Meade Deep-Space DS-10 or DS-16 telescope.

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Each DS-10 and DS-16 is supplied as a complete operating telescope. Included as standard equipment on both telescopes are the complete optical tube assembly, *equatorial* mount, low-profile pier and tripod legs. Electric motor drives, as well as a long list of equipment for advanced applications, are available optionally.

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SPECIFICATIONS:

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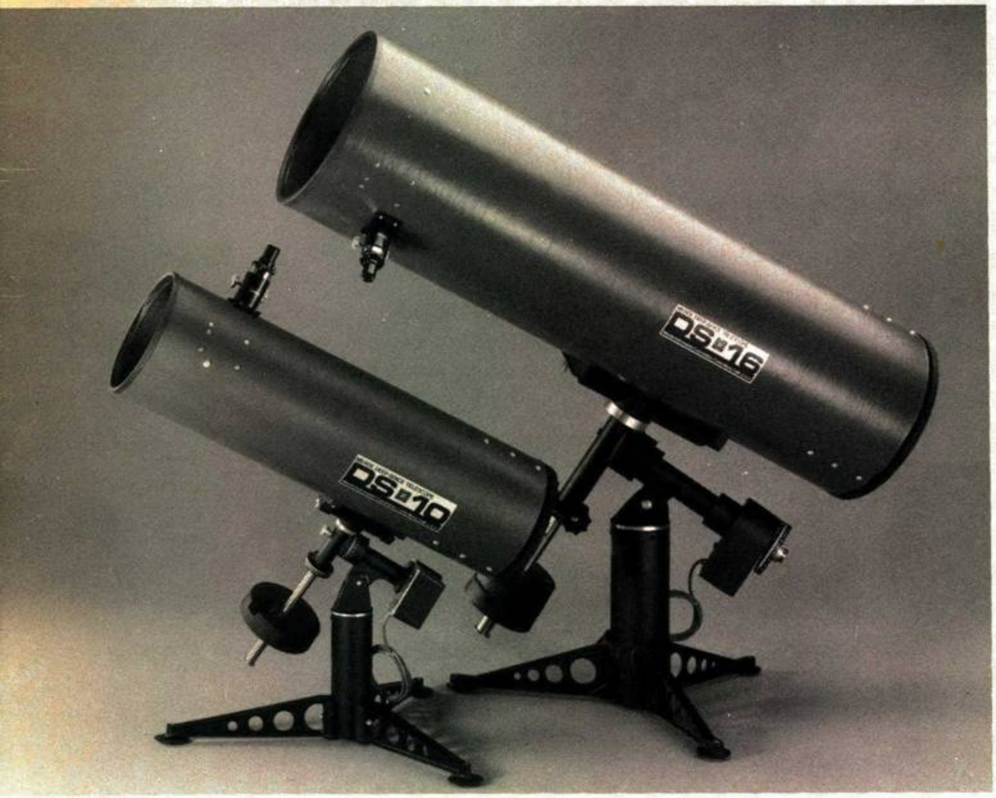
Meade DS-16: 16″ f/4.5 Reflecting Telescope — Includes null-figured, diffraction-limited, Pyrex parabolic primary mirror and matching (4.00″ M.A.) elliptical flat secondary; flotation mirror cell; #67 rack-and-pinion focuser; MA 25mm (73X) coated eyepiece; Sonotube 18″ I.D. x 68″ long, sealed and attractively Zolatone coated; all-metal, precision-machined equatorial mount, with ultrasmooth Nylon bearings, 1½″ solid steel shafts, and 5″ dia. polar thrust surface; low-profile pier and tripod legs. **$1695**

Optional Features — #787 Electric Motor Drive (DS-10); #897 Worm Gear Motor Drive (DS-16); Sealmaster Ball Bearing polar axis (DS-16); 6 x 30mm and 8 x 50mm Viewfinders; Manual Declination Controls; Single- and Dual-Axis Drive Correctors; 2.4″ and 3.1″ Photo-Guide Telescopes; Giant #680 Focuser for 1¼″ & 2″ O.D. eyepieces; Setting Circles.

Meade Deep-Space Telescopes: Giant Apertures at Super Prices!



Meade DS-10 and DS-16, shown with optional motor drives, setting circles, giant focusers.

Meade DS-16 Astrophotos:
(top) Southern region of the Andromeda Galaxy (M31); *(lower)* The Horsehead Nebula. Both photos by Paul Roques.

Dealer Locations and Assistance

For your nearest Meade dealer location, or for free telescope information and assistance, call Meade Instruments toll-free from anywhere in the continental U.S.A. (except California): **1-800-854-7485.** From all other areas, including California, call direct (714) 556-2291.

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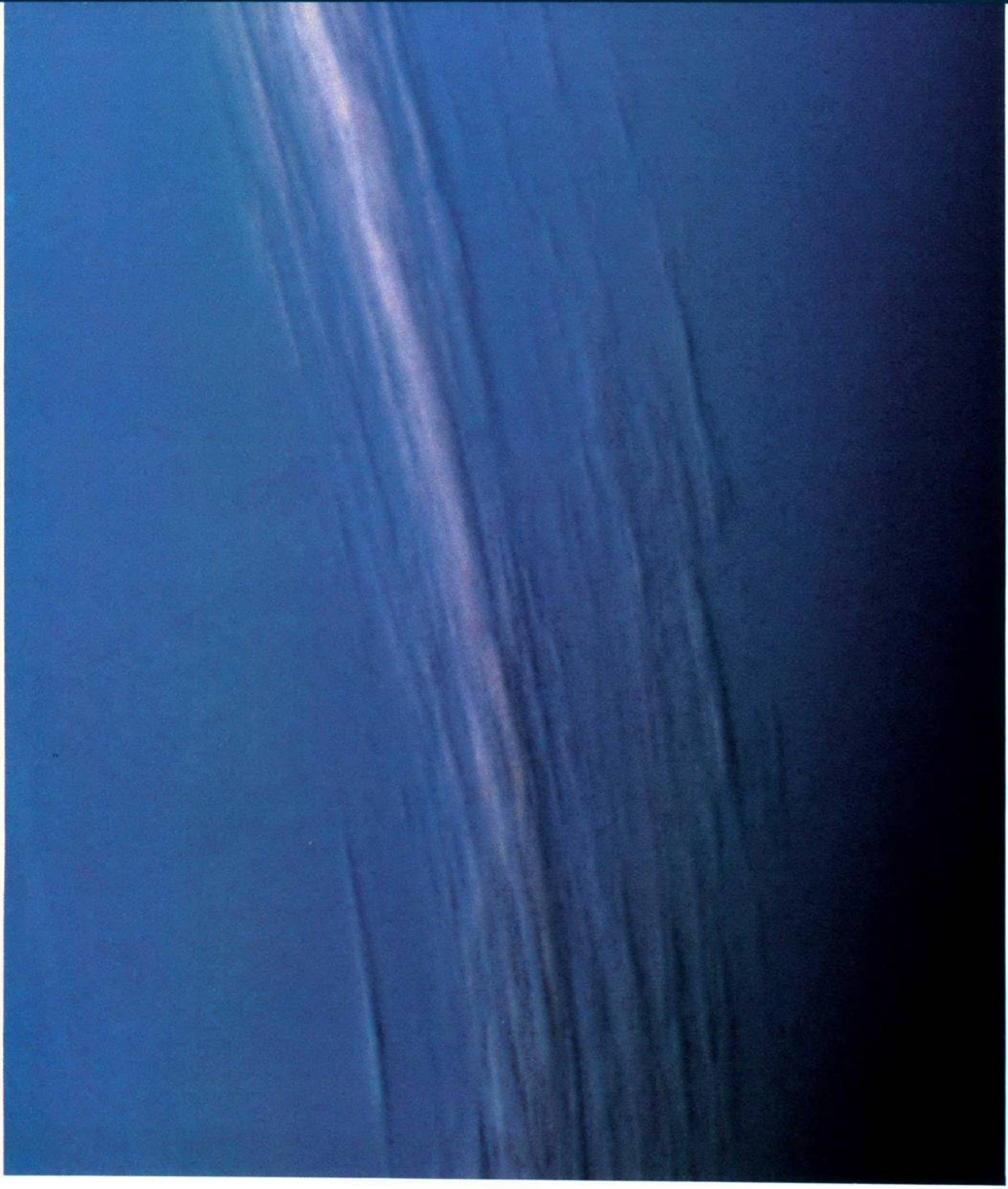
HIGH CLOUDS cast shadows on Neptune's main cloud deck. These white clouds lie about 50 kilometers (30 miles) above the lower cloud layer.

COVER: *Voyager 2* photographed Neptune and its Great Dark Spot, the little white cloud "Scooter," and the eye-shaped storm named Dark Spot 2.



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Behind the Scenes

LIVE FROM NEPTUNE

It was a day and a night of incredible sights. Hour by hour, Neptune grew until it filled the monitors. Cloud features drifted from left to right and disappeared in the Neptunian sunset.

I was covering the *Voyager 2* Neptune flyby from the Jet Propulsion Laboratory in Pasadena, California. Reporters from around the world — crowded shoulder to shoulder in the news room — pounded out stories on personal computers, radio newscasters enunciated their stories into tape recorders, and television reporters stood under bright lights before cameras.

We watched as Triton swelled from a disk the size of a quarter until it filled half the monitor. We saw dark terrain on the northern limb, streaky lines, and soft colors that no one could explain. And we knew that before the next dawn we would know what those features were.

Darkness fell in Pasadena. In the JPL cafeteria we munched slices of pie and drank coffee; three billion miles away *Voyager* sped over the north pole of Neptune. At 10:07 p.m. pacific daylight time, the first of the pre-ring-plane-crossing shots of Triton reached Earth. The surface of the satellite looked weirder than before. And the high-resolution images were due in five hours.

Hours slid by. The distant cameras clicked off frame after frame and transmitted them into space. I lay my head down on a pillow at my desk and imagined the signals speeding past Uranus, Saturn, and Jupiter. Suddenly, the screens lit up as, at 3:37 a.m., the first of twenty-three high-resolution images of Triton reached our eyes.

I am sure that many ASTRONOMY readers stayed up that night with me. Dozens of television stations broadcast those first remarkable pictures of "cantaloupe" terrain, great fissures, strange black plumes, and vast frozen lakes to the waiting world. You joined me in the excitement as our dreams of these unseen worlds melted into the exotic reality that *Voyager* revealed.

This month's feature on Neptune is just the beginning of the story. Because the flyby fell so close to our deadline, this issue presents no more than a first look at what we saw and learned as *Voyager* flew past Neptune. We'll be back next month with an in-depth look at the initial scientific results produced by this most triumphant of space missions.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

Machiavellian Moon Motives

I was appalled at the idea of turning over the Moon to private enterprise suggested in "From Footprints to Foothold" by Robert G. Nichols (July 1989).

Must everything have a dollar value to be justifiable? Greg Maryniak of the Space Studies Institute commented, "We envision lunar bases to be more like North Sea oil rigs and less like the research bases at Little America in the Antarctic." This sickens me. I suppose we should have Exxon run the show!

There is no need to have private industries on the Moon, except to line the pockets of a few corporate executives and to spread the greed and pollution of our nearsighted industrialism.

To walk on the Moon was a triumph, and a lunar observatory is a noble idea. What enlightened person does not ponder the wonders of the universe? But to exploit the Moon for monetary gain would be shameful. I hope I don't live long enough to witness what Mr. Nichols calls "an ambitious plan to explore — and exploit — our satellite." — *Eric Schneider, Tucson, Arizona*

The Sound of Silence

It is frightening that David Eicher recommends stargazing to music from a portable radio or cassette player ("Don't Forget the Bug Spray," August 1989). I spend my days trying to escape their nerve-wracking jangle. I hope he will never decide that my area is a good place for backyard astronomy.

Some of us find healing in the calm beauty of the night sky and the thrill of its special events. Must this be destroyed in an increasingly crowded, chattering, ruthless world? Perhaps some stargazers can be persuaded to give the restorative power of the ancient, starlit silence a chance. — *Elizabeth Lansihg, Sanford, North Carolina*

There Are Good $200 Binoculars

In your July 1989 Viewpoint, Alan Dyer asks, "Why Isn't There a Good $200 Scope?" The reason is because there are good $200 binoculars, available in 7x35 or 7x50. Both of these options are preferable to any telescope of less than 80mm aperture. — *John Landreth, Chapel Hill, North Carolina*

Shot in the Dark

I was very disappointed to read that I had missed the "once-in-a-lifetime" auroral display in New Orleans on March 13, 1989 (AstroNews, July 1989). I have been an amateur astronomer for twenty years and am utterly destroyed because I was not aware of such a fantastic display

Cambridge University Press

The New Physics

Edited by P. C.W. Davies

Davies has collected specially commissioned chapters by eighteen top international physicists that detail everything that is new and most exciting in modern physics.
1989/516 pp./30420-2/Hardcover $49.50

Neutrino Astrophysics

John N. Bahcall

This advanced text provides a lively, thought-provoking, and informative summary of neutrino astrophysics. It combines results from various disciplines to provide a timely and unified discussion of the field.
1989/592 pp./35113-8/Hardcover $75.00
37975-X/Paper $24.95

Stars and their Spectra

An Introduction to the Spectral Sequence

James B. Kaler

Kaler explains the alphabet of stellar astronomy, from cool M stars to hot O stars, recounting the story of their evolution and their place in the universe.
1989/300 pp./16 tables/106 halftone illustrations/54 diagrams /30494-6/Hardcover $29.95

A Manual of Advanced Celestial Photography

Brad Wallis and Robert Provin

Written by two experts in both the practice and theory of astronomical photography, this unique technical handbook for amateur astrophotographers includes a detailed discussion of a topic never before examined in a general survey.
1988/400 pp./25553-8/Hardcover $39.50

Observing Variable Stars

David Levy

This book provides a comprehensive introduction to the field of variable star observation for the amateur. The author explains the ways in which to interpret variation in light output in terms of the life of a star, from birth to sometimes violent death.
1989/224 pp./32113-1/Hardcover $19.95

Introduction to Stellar Astrophysics

Volume 1: Basic Stellar Observations and Data

Volume 2: Stellar Atmospheres

Erika Bohm-Vitense

Volume One is an introduction to the basic elements of fundamental astronomy and astrophysics and serves as a foundation for understanding the structure, evolution, and observed properties of stars. Volume Two contains the basic physical ideas and laws used in the study of the outer layers of a star.
Volume 1: 1989/200 pp./34402-6/Hardcover $59.50
34869-2/Paper $22.95
Volume 2: 1989/250 pp./34403-4/Hardcover $59.50
34870-6/Paper $22.95

Atlas of Uranus

Garry Hunt and Patrick Moore

The book provides the first complete look at the best of Voyager 2's photographs of Uranus from its January 1986 mission. It presents a comprehensive historical background to the discovery of Uranus along with its satellites and rings.
1989/96 pp./34323-2/Hardcover $24.95

The Space Telescope

A Study of NASA, Science, Technology, and Politics

Robert W. Smith with contributions by Paul A. Hanle, Robert H. Kargon and Joseph N. Tatarewicz

Smith and his colleagues describe the history of the planning, building and funding of the Space Telescope, which has been, to date, the most expensive scientific facility ever constructed. They detail the astonishingly complex interactions that took place among the scientific community, government, and private industry in the course of its development.
1989/528 pp./26634-3/Hardcover about $37.50

Bubbles, Voids and Bumps in Time: The New Cosmology

Edited by James Cornell

In this volume, six leading cosmologists provide a current "state of the universe" report: what we have learned about its nature, but also what pieces are still missing from the cosmic puzzle.
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Second Edition

Edited by Jean Audouze and Guy Israel

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1988/432 pp./36360-8/Hardcover $90.00

The Moon Observer's Handbook

Fred W. Price

This book outlines everything an amateur astronomer needs to know in order to undertake lunar observations, including how to make observations, exactly what to look for, and how to record them.
1988/300 pp./33500-0/Hardcover $34.50

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so far south.

I was wondering if auroral events such as this could be publicized before they occur. With sophisticated satellites such as *Solar Max* and *GOES* in place, I don't see why they can't be used to keep the public informed. When a huge solar flare occurs, the next logical step is an aurora. If a public information service could be set up for astronomy buffs, it would give the hobby a great lift and give amateur astronomers the time they need to prepare for such events. — *Kerry M. Finney, Mandeville, Louisiana*

— The Space Environment Services Center in Boulder, Colorado, has a recorded message that details solar activity. The phone number is (303) 497-3235. The recording is updated daily and reports on features such as major flares, predicted solar activity level, and geomagnetic storms.

Although there is a relationship between aurorae and solar flares and information on solar activity is available, there is no infallible method for predicting aurorae. An aurora could appear on any given night at any given latitude.

Share the Wealth

I greatly appreciated Steven Forrest's "Tricks of an Observer's Trade" (Forum, August 1989). I, like the author, just purchased an Odyssey telescope; the article was a real gem because of the tips it furnished about accessories to buy and effective observing techniques to employ.

Such basics are probably old hat to experienced observers, but they're just what I needed to eliminate a lot of expensive and discouraging trial and error. I have read a load of books on astronomy related topics, but Forrest's article had a personal touch to it that I enjoyed. — *Dick Duval, Pittsfield, Massachusetts*

Clarification

In "Debunking Astronomical UFOs" (Forum, December 1988), Willy Smith was referred to as a physics professor at Lycoming College. Mr. Smith has had no affiliation with Lycoming College since 1980, and Lycoming College is not involved in UFO research of any kind. — *David G. Fisher, Lycoming College, Williamsport, Pennsylvania*

ASTRONOMY welcomes comments, corrections, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53217. Letters may be edited for length or clarity. □

Viewpoint

THE NEXT DOOMSDAY IMPACT

by Clark Chapman and David Morrison
Planetary scientists at the Planetary Science Institute in Tucson and the University of Hawaii, respectively, and authors of Cosmic Catastrophes *(Plenum Press, 1989).*

The dinosaurs reigned on our planet for more than 100 million years before a cataclysm wiped the slate clean 65 million years ago. In comparison with the longevity of our reptilian predecessors, *Homo sapiens* has barely gotten a foothold in evolutionary history. In just the last couple of decades, however, our cultural evolution has enabled us to become aware of the nature of the threat that doomed the dinosaurs, which could doom us, as well.

Our planet is a target in the cosmic shooting gallery of high-speed asteroids and comets.

Our planet is a target in the cosmic shooting gallery of high-speed asteroids and comets. Although we don't recommend that anyone run for cover right away, the greatest hazard that we face is that civilization could be entirely destroyed by the unexpected impact of an extraterrestrial object. Yet saving our civilization from destruction by such an impact is not high on the list of national or international priorities. Is this because government leaders have analyzed the situation and decided that the threat is inconsequential? Surprisingly, the answer seems to be "no."

In June 1980, NASA's Advisory Council sponsored a symposium on new directions for the space agency. The group considered various intriguing topics, including the threat posed by an asteroidal impact. They concluded that the threat was sufficient to take action, and they proposed "Project Spacewatch" to deal with it. The idea was to build optical and radar telescopes capable of discovering the potentially threatening asteroids and comets, and then — in the unlikely event that one should be found to be on an eventual collision course with Earth — to undertake a rendezvous space mission to "give the object the proper nudge," perhaps by exploding a bomb alongside it.

NASA followed up the Spacewatch idea by asking the Jet Propulsion Laboratory to run a workshop on the topic a year later. The workshop concluded that each year the probability of the destruction of our civilization is about 1 in 300,000. That's about 1 chance in 6,000 of such an impact happening during a person's lifetime.

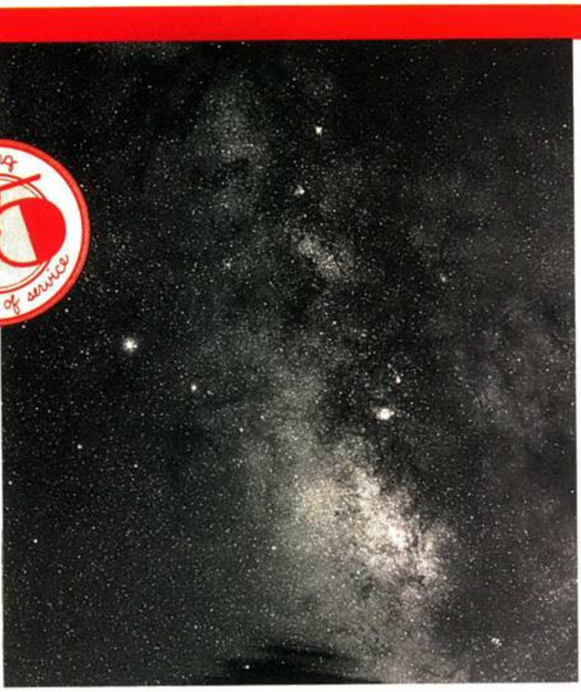
But what do these probabilities mean? Should we shrug our shoulders and watch the next TV program? Or should we rally the nations of the world to mount a Project Spacewatch to remove this threat from hanging over us? All in all, an individual's risk of being involved in this cosmic catastrophe — whether or not he or she actually dies in it — is something like the chance that a typical American will die by accidental electrocution, or several times the chance of dying in a major airplane crash.

You might object and say, "But people are electrocuted every day, and nobody has been killed by an asteroid impact — the numbers must be wrong." But the numbers are roughly correct. These statistics refer to an individual's risk, and you have not been electrocuted or died in a plane crash, nor, the chances are, has anyone you know. But if an asteroid crashes, which happens much less frequently than an airplane crash, we might all go together.

In our view, there is no need for urgency. At odds of 1 to 300,000 per year, we can afford to wait a few years to prepare for this contingency in an orderly, intelligent way. But to let this threat slide for decades without action would be to treat our whole society the way a smoker treats his or her life: irrationally.

The first thing we would recommend is renewed thinking on the issue. The wide range of uncertainty in the Spacewatch estimate could be narrowed. Provided that the best estimate of the threat to civilization remains greater than a chance per million per year, we think it would be only prudent to mount a search for the potential impactors. We should also clarify the appropriate method for ameliorating a potential impact.

If it is worthwhile to buy home fire insurance or state lottery tickets, it is sensible to invest in further knowledge about the threat from the skies. If nothing is discovered to be on a collision course, we will have lost nothing. If, instead, a doomsday impact is discovered and averted, then we will have made one of the most important contributions to human civilization in history. □



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The Milky Way photographed by Tom Orzechowski.

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62 camera adapter	$35
36 hand control for MTS	$99
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1401 tube balance system 8"	$89
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43 varipak drive corrector for SCT	$99
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280 PG guide scope w/brackets	$149
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accessory shelf	$29
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1.25" screw in color filter	$15
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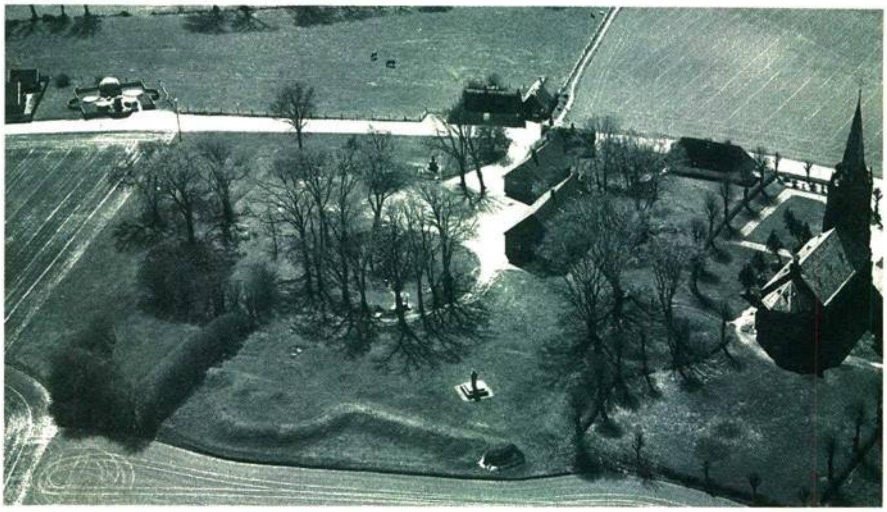

ABANDONED SINCE 1597, Tycho Brahe's Uraniborg observatory may soon be restored. This view looks southwest across the ruin and shows the restored annex Stjerneborg at upper left.

The bluff island of Hveen, three square miles in size, lies in the Sound halfway between Denmark and Sweden. Today, it is a breezy, pastoral place, with views of the sea in all directions and is populated mainly by farmers, dairy herds, and summer vacationers. In the 1580s, however, Hveen was the site of the most famous observatory in all Europe, Uraniborg, run by the greatest astronomer of the age, Tycho Brahe. Little is now left of Uraniborg, but it may soon be restored, at least in part, if a Swedish organization gets its way.

Tycho built Uraniborg with the support of the king of Denmark, who also made him feudal lord over the island and its inhabitants. It was here, a generation before the invention of the telescope, that Tycho compiled a long series of observations of planet positions using highly accurate sighting instruments of his own design. These observations, particularly of Mars, gave his last assistant, a genius named Johannes Kepler, all the data necessary to formulate the three basic laws governing planetary motion.

Uraniborg was active for about twenty years when a quarrel broke out between Tycho and the king's successor, who was less impressed by Tycho's widespread fame and disturbed by his reckless finances and imperious nature. In 1597 Tycho abruptly quit the island and moved his household and instruments to Prague, where he died four years later. Uraniborg, abandoned to the winds and rain, soon fell to ruin.

In 1987 a Copenhagen architect, Sven-Ingvar Andersson, proposed that the foundations of Uraniborg be restored, along with part of the formal garden that surrounded it. A small museum had been built at the site in 1931, and in 1946 a statue to Tycho was erected. In recent years, archaeologists restored the observatory's annex, Stjerneborg, which Tycho had built one hundred feet southeast of the main building to house additional instruments and observers. Visitors can now enter the annex's underground chamber and see where the great astronomer made observations. But almost nothing of Uraniborg's lofty main structure is left today.

Andersson acknowledges that rebuilding all of Uraniborg would be far too costly. Instead, he suggests that an open steel frame be erected in its place. This would show the size of the building and its orientation, much as a similar frame on Philadelphia's Independence Mall locates the long-vanished house where Benjamin Franklin lived.

The 9-foot walls that originally surrounded the observatory offer better prospects for detailed restoration. Wholly vanished in places and greatly weathered everywhere, the walls are now just a couple of feet high and can be seen clearly only on the northeast side. Andersson suggests that the walls could be left just as they are, stabilized and marked more clearly, or reconstructed to the extent permitted by the scanty records that survive. If the walls are to be restored, Andersson notes that some helpful experience could be gained from the restoration of Kronborg Castle at Helsingor, Denmark (*Hamlet*'s Elsinore), because the structures were built at roughly the same time.

The plan for Uraniborg's restoration calls for tearing down an old schoolhouse at the site. The garden walls on three sides would then be stabilized and at least part of the fourth side would be rebuilt completely. The formal garden would come next, including gazebos, fences, and geometric pathways. Restorers would draw on existing plans of Italian gardens from the same period. Finally, the steel frame would be erected to locate the observatory building itself.

The project is headed by the Landskrona (Sweden) County Architect, which has sought funding from several Swedish businesses and foundations. (Although Hveen was Danish in Tycho's day, it now belongs to Sweden.) In addition, a well-funded Copenhagen planetarium has expressed an interest in the Uraniborg restoration, and much favorable publicity has been generated in both countries.

The project, which needs the equivalent of $800,000, has raised about $300,000 toward the goal. The project has the support of the Swedish National Office of Antiquities and will be carried out by Landskrona County if all the funds are raised. — *Bertil Haggman*

IAPETUS: SATURN'S HARLEQUIN MOON

Saturn's eighth satellite, Iapetus, is one of the solar system's most unusual moons. Iapetus is five times brighter at western elongation (magnitude 10.1) than at eastern elongation (11.9) and it slowly circles Saturn in an 80-day orbit at about three times the distance of Titan. Alternately showing its dark leading hemisphere (eastern elongation) and its bright trailing hemisphere (western), harlequin Iapetus has long puzzled astronomers, who immediately noted the brightness asymmetry when the moon was discovered in 1671.

Two recent discoveries paint an interesting picture of the moon's history. The first focuses on why the moon has such a marked asymmetry. Ronald Tabak and Warren Young of Youngstown State University in Ohio examined the question in an article in the journal *Earth, Moon, and Planets*. They believe that a comet struck

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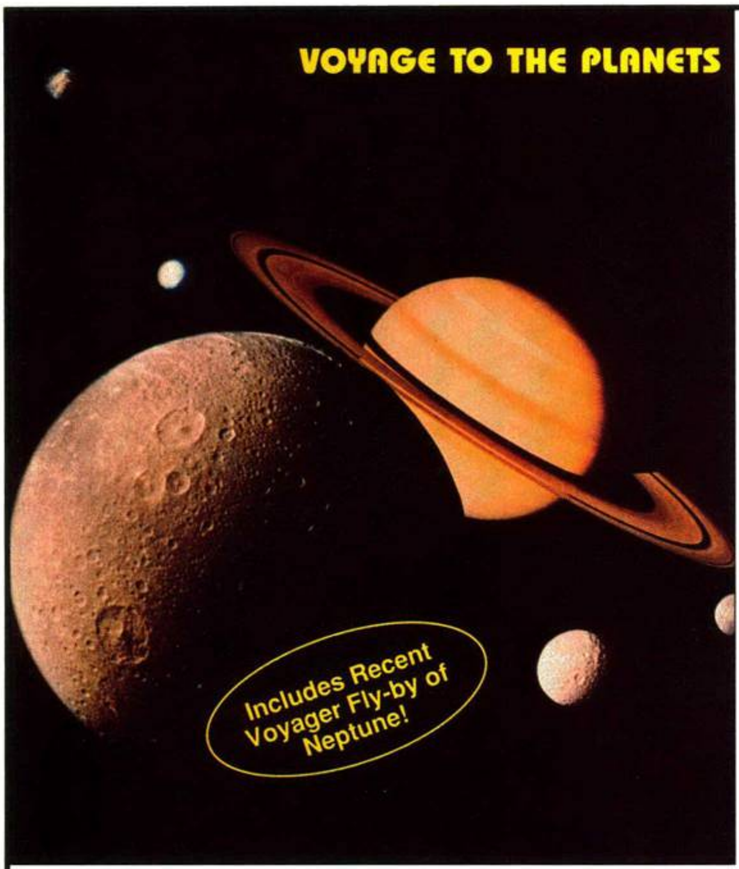

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Iapetus and coated the front side of the moon with a thin layer of dark dust. Yet the dark material isn't simply the residue of the impact: comets, after all, are mostly ice and, initially at least, the impact area would have looked as bright as the rest of Iapetus — about 50 percent reflective. Instead, the actual course of events Tabak and Young propose would have been much more interesting.

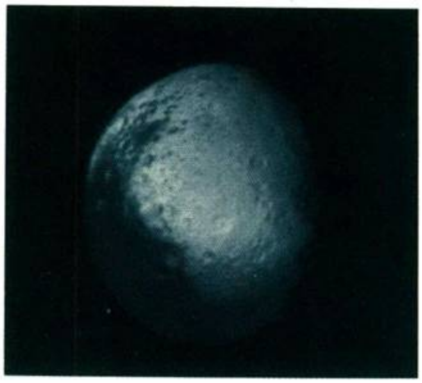
They suggest that a winnowing process separated the icy component of the comet from the dusty component and allowed the latter to collect on the front hemisphere of the moon. The main clue pointing to the process is that the dark matter covers about 110° of latitude (in the north-south direction) but almost 270° of longitude (east-west). In fact, the dirt wraps so far around Iapetus that the brightest part of the moon isn't the center of the trailing hemisphere, but the polar regions.

Why is the location of the dark matter important? Computer simulations showed Tabak and Young that if a comet were to strike Iapetus, the moon would partially lose its tidal lock on Saturn. (Like our Moon, Iapetus keeps one side turned always toward Saturn.) The computer models indicate that for about five years after the impact, Iapetus would ponderously swing back and forth around its polar axis.

Immediately after the impact, the moon would quickly be enveloped in a cloud of dust and vaporized ice composed of cometary material and material native to Iapetus. Because the vapor molecules would be much smaller and lighter than the dust grains, the impact would have accelerated the vapor molecules to higher velocities and most would soon dissipate. The dust particles would also be sped up; however, being larger and heavier, more dust particles would remain in orbit with Iapetus. During many circuits of Saturn, the front side of Iapetus would gradually darken as the dust collected on the leading face, and the moon's slow, side-to-side nodding would strew the dark material over a larger range of longitude than its north-south spread.

The scientists note that the collision-generated nodding would quickly die away, and random impacts from meteoroids and ice will erase all trace of the "harlequin" pattern from Iapetus in less than a billion years. Therefore, they remark, the collision with the comet was an event both relatively rare and recent.

Iapetus was the right size to be thus affected by the impact. If the moon were as big as Ganymede, little of the ejecta from the impact would have escaped and the vapor would have recondensed on the moon, blanketing any asymmetrical dust accumulations. And if Iapetus were much smaller, the impact would have either broken it apart or the moon would have completely lost its tidal lock on Saturn and the dust would have been evenly distributed all around it.



WHERE DID IAPETUS GET such a dirty face? A new theory pins the blame on comet dust swept up after a large impact on the moon.

The second discovery looks at possible constituents in the dark material. Writing in *Science*, Edward A. Cloutis of the University of Alberta compared the spectral reflectance of the dark material with terrestrial tar sands, which contain clay, water, and various hydrocarbons such as bitumen. Although the match was not ideal, Cloutis found good general agreement with a mixture of 90 percent clay and 10 percent coal tar.

CONTINENTS ON TITAN?

For the first time, a radar signal has been used to probe beneath the opaque orange hydrocarbon smog that conceals the surface of Titan, Saturn's largest moon. The results of the experiment show that while Titan may have the ethane ocean postulated to exist by some scientists, the ocean is not global and may have "dry land" — continents —rising above it.

A research team led by Duane O. Muhleman of Caltech sent a 360-kilowatt signal from NASA's 230-foot Goldstone antenna in California. Two and half hours later a very faint signal — "the weakest such echo that has ever been measured," said Muhleman — trickled back from Titan and was picked up by the Very Large Array radio telescope in New Mexico. (The team used this same procedure to study Mars; see AstroNews, July 1989.)

The radar experiment took place on June 3, 4, and 5, 1989, and viewed different faces of Titan, which rotates 23° per Earth day. On the 3rd and 5th of June, the echoes were barely detectable. Muhleman noted that a deep ethane ocean with a smooth surface would produce just such a weak signal. But on June 4, in the middle of the experiment, the VLA received a stronger echo with much the same signature as radar echoes from Venus. This indicates that the surface detected was much rougher than the surfaces sampled on the other two days. The most likely explanation, according to Muhleman, is that the beam was "seeing" a continent that is roughly 500 miles across and made of water ice, dry ice, and rocky fragments.

The experiment strongly supports placing an imaging radar aboard the joint U.S.-European Space Agency Saturn probe *Cassini*, now under development. Mission planners had been considering deleting the instrument from *Cassini*, but with a landscape to be mapped, flying an imaging radar will now get high priority.

REPLACEMENT FOR COLLAPSED RADIO TELESCOPE APPROVED

Congress has appropriated $75 million to the National Science Foundation to construct a large, single-dish radio telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia. The Green Bank Telescope, which will be at least 100 meters (330 feet) in diameter, will replace the 300-foot radio telescope that collapsed at Green Bank last November (see AstroNews, February 1989). Located in the heart of the National Radio Quiet Zone, the telescope will be free from the interference that plagues many other radio telescopes.

The new instrument will be the world's largest fully steerable radio telescope. The design gives astronomers a unique instrument, one capable of observing both the weakest radio sources and surveying large areas of the sky in search of unusual radio-emitting objects. The state-of-the-art antenna will make precise observations over a wide range of radio wavelengths, from short millimeter waves to meter-length waves.

The preliminary design for the telescope should be complete by the end of this year and the detailed engineering design will be ready by the end of 1990. Construction of the telescope will take place from 1991 to 1994, with testing of the finished antenna scheduled for 1994. When the Green Bank Telescope achieves full operation in 1995, it will fill a unique niche in radio astronomy well into the twenty-first century.

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Space News

HIPPARCOS FAILURE STUNS EUROPEANS

Space scientists in Europe were devastated by the recent failure of the *Hipparcos* astronomy satellite, which was to have measured the positions of nearly 500,000 stars during a three-year program. The *Hipparcos* tragedy is the first time the European Space Agency has failed with a scientific mission.

Hipparcos, the High Precision Parallax Collecting Satellite, was successfully launched on August 8 from Kourou, French Guiana, and placed in an elliptical orbit. Thirty-seven hours into the mission, the satellite's propulsion system that was to have placed it into a circular orbit 22,300 miles above Earth failed to ignite. Several attempts were made during the following week to fire the apogee boost motor, but all were unsuccessful.

In late August *Hipparcos* was in a stable orbit, circling Earth every ten and a half hours. At the outermost point in its orbit, the satellite reaches the planned altitude, but it is only 130 miles high at the lowest point in its orbit. Aside from being in the wrong orbit, all other systems on the satellite are healthy.

The satellite was the most important scientific satellite ever funded by the European community. It was to have made high-precision measurements of the motions, positions, and distances to 120,000 stars and less-precise measurements of an additional 400,000 stars, increasing the volume of space for which we have reliable stellar distances by a factor of 100.

Within 100 light-years of the Sun, distances to stars are found by conventional surveying techniques. The annual motion of Earth around the Sun leads to a systematic shift in the apparent position of a star, known as parallax. The size of the parallax shift gives a direct measurement of distance.

Unfortunately, turbulence in our atmosphere limits the accuracy of Earth-based measurements. The idea behind *Hipparcos* was to put a parallax telescope in Earth orbit where the conditions of weightlessness, thermal stability, and the absence of atmospheric turbulence give a clear view of the entire celestial sphere.

One crucial objective of the mission was to determine accurately the luminosities of fifty-five Cepheid variables, which are widely used as "standard candles" in judging distances to other galaxies. About thirty nearby galaxies are close enough for us to see their Cepheids. With the *Hipparcos* data, astronomers hoped to map out the structure of our local extragalactic neighborhood more precisely. Ultimately, this would have improved our knowledge of the distance scale in the remote universe populated by quasars and active galaxies.

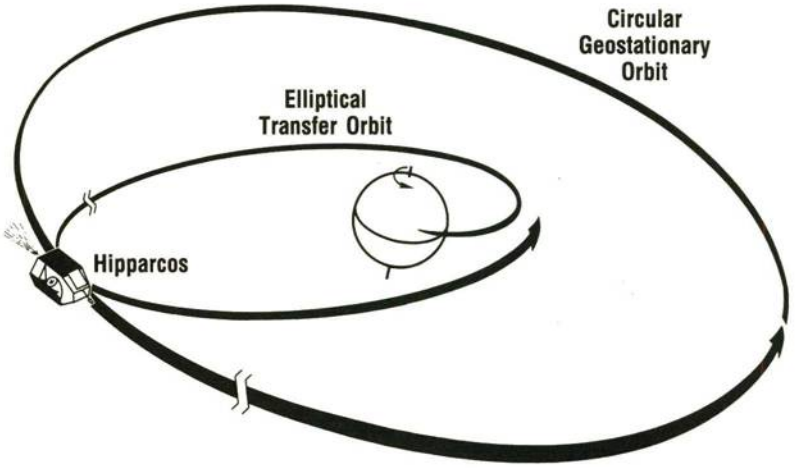
Europe's astronomers are now coming to terms with the fact that the mission has been ruined by the failure of a simple boost motor that had been tested and used many times before. Engineers consider this engine so reliable that they do not bother to include diagnostic features that might now tell them exactly what went wrong.

In its current orbit the satellite can send data to the European Space Agency's ground station in Darmstadt, West Germany, for only three hours a day. Worse than that, the satellite is traveling through the Van Allen radiation belts where charged particles will soon damage its electronic equipment and solar arrays.

Mission planners are continuing efforts to fire the boost motor. According to project scientist Michael Perryman, *Hipparcos* is still capable of collecting some measurements. "We will still produce a catalog of 120,000 stars, but probably with less accuracy," Perryman said at a press conference on August 17. "The precision will be a factor of 10 less than expected, but we still hope to achieve a positional accuracy fifteen times higher than from the ground."

For the more than one hundred mission scientists working in the twelve member nations of the European Space Agency, the tragedy is ten years of scientific effort down the drain. Floor van Leeuwen of the Royal Greenwich Observatory devoted eight years to writing computer software for the mission. *Hipparcos* was to have sent data back so fast that ten high-density magnetic tapes would be filled every week. "Now all we have left is the experience of the people," said van Leeuwen. "It is just beginning to sink in. What do we do next if there is no follow-up mission?"

Van Leeuwen and other astronomers are fighting to persuade the European Space Agency to fund a replacement. *Hipparcos* cost $300 million and a replacement will cost $150 million. Early indications, according to van Leeuwen, are that the French and Italian governments are in favor of a replacement. It will take about three years to get a second *Hipparcos* ready for launch. In that time the scientific teams may well disintegrate as individuals move on to different areas of research. — *Simon Mitton*



UNABLE TO REACH its planned circular orbit because of a failed propulsion system, *Hipparcos* will be unable to complete its mission of recataloging nearly 500,000 stars.

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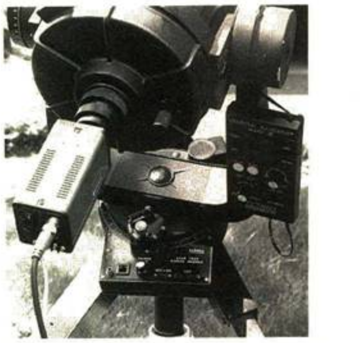

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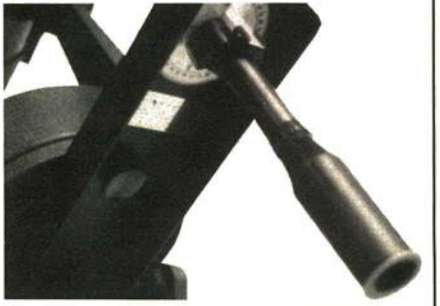

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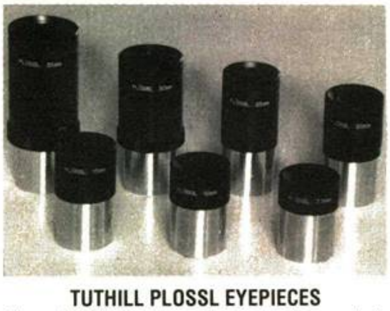

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TELESCOPES HIGHLIGHT STELLAFANE

Intermittent thunderstorms threatened to halt activity at this year's Stellafane convention, held in Springfield, Vermont, on August 4 and 5, 1989. Despite the inclement weather, which occasionally unleashed a driving rain on Breezy Hill, nearly two thousand amateur astronomers from across the nation — and a few from Britain, Germany, and other foreign locales — kept relatively dry and enjoyed telescopes, talks, and new meetings with old friends.

Friday evening, August 4, saw sputters of rain cover the field, necessitating the use of plastic covers on the relatively few telescopes that optimistic amateurs had set up on the hill. Huddling under a large tent erected behind the Stellafane clubhouse, several hundred attendees confined their activities to listening to two dozen or so amateurs give brief, informal slide shows on topics ranging from astrophotography to telescope building.

The skies darkened early on Saturday morning, deluging Breezy Hill and postponing activities until mid-morning, when the storm subsided. Dedicated amateurs who brought homebuilt telescopes set them up around the clubhouse, while others milled about the swap-meet tables, looking for bargain mirrors, eyepieces, and books. By noontime the sky cleared and sunlight illuminated the grounds.

Innovation was the key word to describe many of the best scopes that occupied Breezy Hill. Lee Waddell of Lebanon, Pennsylvania, brought a finely crafted 12.5-inch f/8.9 reflector that he built from scratch and optimized for planetary viewing. The scope's fiber glass tube contained many amenities, such as a heated front element that eliminates dewing, rotating lockable rings that move only the front cell, and an internally mounted filter wheel that allows different filters to be rotated into the light path behind the eyepiece drawtube.

Long-focus reflectors with exotic optics configurations were also popular at this year's meeting. John Vogt of the Astronomical Society of Long Island brought a just finished 12.5-inch f/20 Buchroeder Tri-Schiefspiegler with a tube constructed of birch veneer over aluminum. Bill Benesch of Western Springs, Illinois, brought a 5.5-inch f/15 Daley-Durocher telescope that employs a spherical primary mirror and a flat solar filter that acts as a secondary mirror. The result was extremely sharp, large-scale views of the Sun.

Dobsonian reflectors are very much a part of things. This was demonstrated by Alan Green's 17.5-inch f/4.5 telescope, crafted from molded fiber glass in breakdown sections. Disassembled, the telescope fits into Green's Toyota for a drive to dark skies. Franklin Morgan of Rock Hill, South Carolina, brought a 10-inch f/5.6 Dobsonian binocular made from Sonotube and birch plywood that can be collimated more easily than earlier binocular telescopes.

Proud craftsmen also brought smaller, less-complicated telescopes. John Dethoff of Reading, Pennsylvania, brought what he called a "Quackstar," a 4.25-inch f/5 telescope that serves as a handy telescope for camping expeditions with his children. (An osteopathic surgeon, Dethoff constructed the tripod legs from children's crutches.) Alan Koenig, a 15-year-old telescope maker from Clifton, New Jersey, brought what he called simply "radiotelescope." It consists of an 80mm copy scope placed inside an antique radio that plays any station within range for entertaining observing sessions. (For a full report on telescopes at the 1989 Stellafane convention, see *Telescope Making #38*.)

On Saturday evening Walter Scott Houston, longtime columnist for *Sky and Telescope*, gave his annual "Twilight Talk." Houston reflected on the long history of Stellafane and then introduced Roger Tuthill, who shared his experiences associated with operating a telescope business and chasing solar eclipses for the past thirty years. After the talk, the sky briefly cleared. But the clearing didn't last, and participants left this year's convention hoping for better weather next year.

AMATEUR PROJECTS SELECTED FOR SPACE TELESCOPE

Projects designed by five amateur astronomers have been accepted as scientific experiments that will be carried out by the *Hubble Space Telescope*. NASA announced the five projects, selected from several hundred possibilities, in August. The measure is a goodwill act from NASA designed to demonstrate the scientific validity of ideas

SOLAR OBSERVING with Bill Benesch's 5.5-inch f/15 Daley-Durocher telescope highlighted afternoon activities at this year's Stellafane convention.

developed by amateurs.

The amateurs selected range from a computer scientist to a homemaker to a self-employed museum volunteer. Ray E. Sterner, a computer scientist at Johns Hopkins University in Baltimore, will study mysterious luminescent arcs discovered recently in galaxy clusters. With the *Space Telescope*'s Faint Object Camera, Sterner hopes to confirm his idea that the arcs result from clusters of new stars produced along a shock wave, like snow pushed ahead of a plow.

Ana M. Larson, a homemaker and mother of two from Seattle, hopes to find massive protoplanets encircling nearby stars. Larson will use the *Space Telescope* to examine nearby regions of star birth, looking for planets several times the diameter of Jupiter.

Theodore J. Hewitt, a self-employed museum volunteer from Berkeley, California, wants to use the *Space Telescope* to observe a nova. As soon as a nova occurs, Hewitt will use the extraordinary flash of light produced by the star to observe the icy shell of comets encircling the star. Astronomers believe these shells of ice exist around all stars but have never observed one because they are too faint to see under ordinary circumstances.

James J. Secosky, a science teacher at Bloomfield Central near Rochester, New York, wants to search for frost forming on the surface of Jupiter's moon Io. *Space Telescope*'s high-resolution camera will allow Secosky to observe very close to the bright limb of Jupiter and glimpse Io emerging from the giant planet's shadow. Astronomers have observed that Io is slightly brighter after spending some time behind the big planet. The theory that Io's surface freezes hard in the cold and therefore reflects more light will be tested by Secosky's experiment.

Peter J. Kandefer, a consultant and electronics engineer from Massachusetts, will study light fluctuations and turbulence in the atmosphere of a peculiar variable star. The star has magnetic fields ten times stronger than those of our Sun and expels million-degree plasma at a high rate. Using the *Space Telescope*'s High Resolution Spectrometer and High Speed Photometer, Kandefer will study changes in the star's activity throughout one week.

Space Telescope is scheduled to be launched in March 1990. Astronomers from the Space Telescope Science Institute will schedule and execute the amateur proposals in the same manner as programs for professional astronomers. The astronomers will also assist the amateurs with a scientific analysis of the resulting data, which will eventually be published in a scientific journal. □

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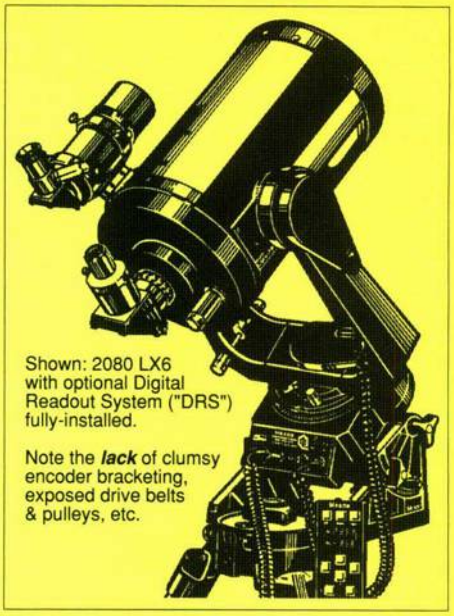
LX6's


Shown: 2080 LX6 with optional Digital Readout System ("DRS") fully-installed.

Note the ***lack*** of clumsy encoder bracketing, exposed drive belts & pulleys, etc.

Meade's new LX6's boast an *f*/6.3 optical system which permits astrographic exposures in only four-tenths of the time required by an *f*/10 system! In addition, they come complete with quartz-locked, micro-computer-controlled, electronic pulse-motor drive, sophisticated hand control unit with astrographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces, giant 9x60mm finderscope, built-in provision for optional DRS or CAT system, and more!

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2080 LX6	(List:$4,400)	CALL
2120 LX6	(List:$6,400)	CALL

(These 'Scopes also available with optional new Heavy-Duty Wedge)

Package: Telescope *and* Optional Digital Readout System, together:

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2120 LX6, *with* Mod. 9070 DRS	(List:$7,100)	CALL

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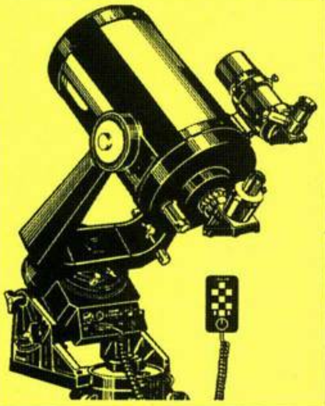
Meade's CAT's and DRS's are bolt-on, plug-in units. They can be installed by anyone who is comfortable using simple hand tools. However, if you are concerned about mechanical or electronic assembly, we offer installation services for our telescope customers when the telescope and digital accessories are purchased at the same time. Please contact us for information, details and pricing.

Meade LX5's



Fully equal to LX6's in terms of their standard equipment, they come complete with quartz-lock microelectronic pulse motor drive, sophisticated hand control unit with photographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces,

& giant 9x60mm finderscope!

Specs: 2080 LX5 and 2120 LX5: Complete 8"A (2080 LX5) or 10"A (2120 LX5) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated-reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 26mm Super Plossl eyepiece, 1.25" (77x or 96x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz micro-electronic sidereal-rate pulse-motor drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit; 115Vac 60Hz AC power adapter with 25 ft. cord; DC battery-pack *(batteries not included)* with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level, magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; audio cassette instructions; instruction manual; limited lifetime warranty.

2080 LX5, Wedge, Tripod (as above)	(List: $ 3,800)	CALL
2120 LX5, Wedge, Tripod (as above)	(List: $ 5,400)	CALL

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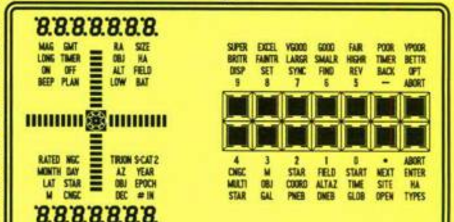
Meade's CAT System

Meade's **C**omputer-**A**ided **T**elescope (the "CAT") system has most of the advantages of a computer-***controlled*** telescope at only a fraction of the cost. The CAT can readily and quickly help you find any of the thousands of celestial objects whose coordinates and other descriptive data are stored in its memory, ***including all of the planets***, as well as any other celestial object of known coordinates (comets, asteroids, quasars, super-novae, etc.). The CAT is loaded with extra features and functionality as the panel legends, at right, indicate.



For the computer-literate, there is also a version of the CAT with an RS-232C port (the "CAT-COM") for connection to a "PC"-type personal computer. CAT-COM includes 4 demo programs, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software (source & executable) is supplied on a 5.25" 360Kby disk.

Optional Computer-Aided Telescope (CAT) System:

CAT, 2080 *or* 2120 LX6	(List: $1,590)	CALL
CAT-COM, 2080 *or* 2120 LX6	(List: $1,850)	CALL

Package: Telescope *and* Optional CAT System, together:

2080 LX6 *with* CAT	(List: $5,990)	CALL
2080 LX6 *with* CAT-COM	(List: $6,250)	CALL
2120 LX6 *with* CAT	(List: $7,990)	CALL
2120 LX6 *with* CAT-COM	(List: $8,250)	CALL
Catalog Listing, CAT Database	(List: $ 60)	CALL

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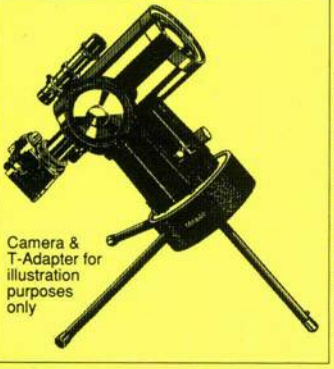
2045-D(igital)


Camera & T-Adapter for illustration purposes only

This is Meade's go-anywhere, do-anything telescope. Small and light enough to maximize its portablity, it nevertheless has sufficient aperture and focal length to permit enjoyable astronomical viewing. And, the new 12VDC drive system permits it to be operated worldwide (N or S hemisphere, too) from a small battery pack. It can also double as a high-quality terrestrial spotting scope or telephoto camera lens.

Specs: 2045-D: Complete Schmidt-Cassegrain telescope tube assy (f/10, 102mmA, 1,000mmF) with certified diffraction-limited optical system; high-transmission anti-reflection coatings on corrector plate; ultra-smooth anti-back-lash focuser; 5x24mm finderscope; 1.25" prism-type stardiagonal/eyepiece holder; 25mm eyepiece (40x); rugged dual-fork astro mount, with DC digital-electronic tracking motor built into base and N-S hemisphere switch; graduated setting circles, manual positioning controls & clutches on both axes of motion; tabletop tripod legs (adjustable for latitude); dust covers; DC power cord and battery pack (batteries ***not*** included); instructions; limited lifetime warranty.

Please inquire regarding availability of Tripod, Wedge, Carrying Case, etc.

2045-D, HTC (as above)	(List: $ 1,300)	CALL

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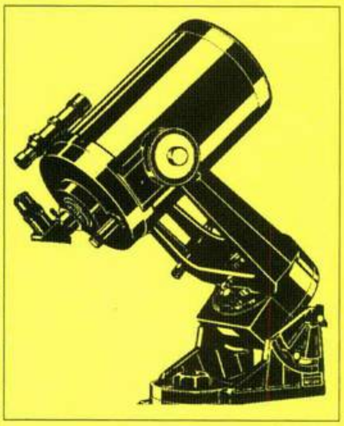
Meade 2080



Specs: Standard 2080-A: Complete 8"A f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm aperture, 2,000mm focal length); 6x30mm viewfinder; 1.25" eyepiece holder; 1.25" prism-type star diagonal; 25mm (80x) MA eyepiece, 1.25" barrel; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; AC hysteresis-synchronous tracking motor and worm-drive gearing built into telescope drive base; 115Vac 60Hz AC power cord; Equatorial Wedge with no-tool knob set; adjustable-height Field Tripod; dust covers for optical apertures; instruction manual; limited lifetime warranty.

Specs: Standard 2080-B: The "B" model includes all above, plus MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors, for increased image brightness, contrast and clarity.

Premium Accessory Upgrade: Either of the telescopes above is available with the following premium accessories substituted: giant 9x60mm illuminated-reticle polar-alignment viewfinder; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000, 26mm Super Plossl eyepiece, 1.25" (77x);

2080-A, Wedge, Tripod (as above)	(List: $ 1,738)	CALL
2080-A, *plus* Premium Accessory Package	(List: $ 2,238)	CALL
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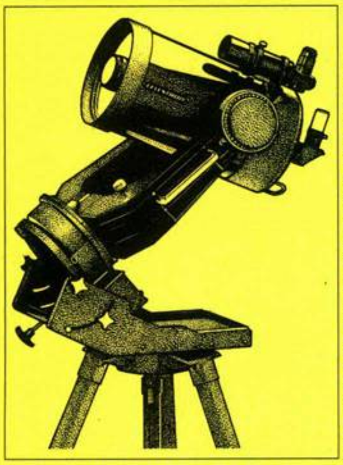
CELESTRON® COMPUSTAR

ULTIMA C8



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Ultima 8, StrBrt, Wedge, Tripod (as above) .... (List: $ 3,328) .... CALL

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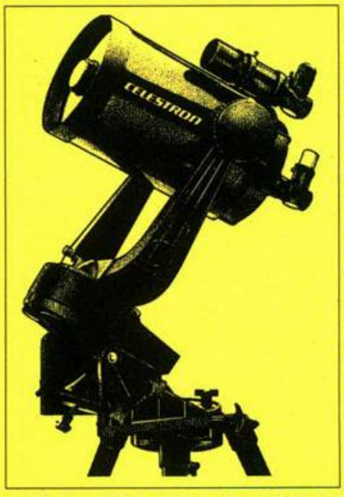
PowerStar IV

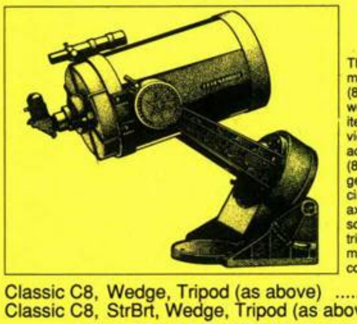


Complete 8" Schmidt-Cassegrain telescope tube assembly (f/10, 203mmA, 2,000mmF), with Celestron's world-famous, hand corrected, diffraction-limited, laser tested optical system; StarBright optical coatings group; DewStar lens-shade; widefield 8x50mm right-angle finderscope with built-in illuminated polar-alignment reticle; 1.25" visual accessory holder; 1.25" star diagonal; 30mm (68x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; 7mm (286x), 1.25" barrel, fully coated, premium-grade, high-power Orthoscopic eyepiece; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz microelectronic sidereal-rate pulse-motor drive system and ultra-precision 7.5" diameter worm-drive gearing built into telescope drive base; drive corrector hand control unit, with additional controls, and connectors for optional accessory electronic equipment; AC power adapter and cord/plug; DC battery-pack *(batteries not included)*; car-battery power cord/plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth adjustments, latitude scale, bubble level and no-tool knob set; heavy-duty adjustable-height Field Tripod; dust covers for optical apertures; extra-rugged molded carrying case for scope-tube/fork-mount/drive base assembly, with die-cut foam lining and room for accessories; T-Adapter; piggyback mount; Instruction Manual; Product Guide and Reference Manual; limited lifetime warranty.

PwrStr IV, StrBrt, Wedge, Tripod (as above) ...... (List: $ 2,758) .... CALL

FREE FREIGHT! (UPS Ground) for the POWERSTAR IV above

CLASSIC C8



The CLASSIC 8 is the perfect telescope for the budget-minded buyer. Complete f/10 telescope tube assembly (8" aperture, 2032mm focal length), with Celestron's world-famous, individually hand figured, diffraction-limited, laser tested optical system; widefield (8.0° field-of-view) 6x30mm straight-through finderscope; 1.25" visual accessory holder; 1.25" prism star diagonal; 25mm (81x), 1.25" barrel, multi-coated, Kellner eyepiece; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; electric AC motor tracking system in telescope drive base; equatorial wedge; adjustable field tripod; dust covers for optical apertures; instruction manual; limited lifetime warranty. **StarBright** optical coatings are optionally available.

Classic C8, Wedge, Tripod (as above) .... (List: $ 1,748) .... CALL
Classic C8, StrBrt, Wedge, Tripod (as above) .... (List: $ 1,928) .... CALL

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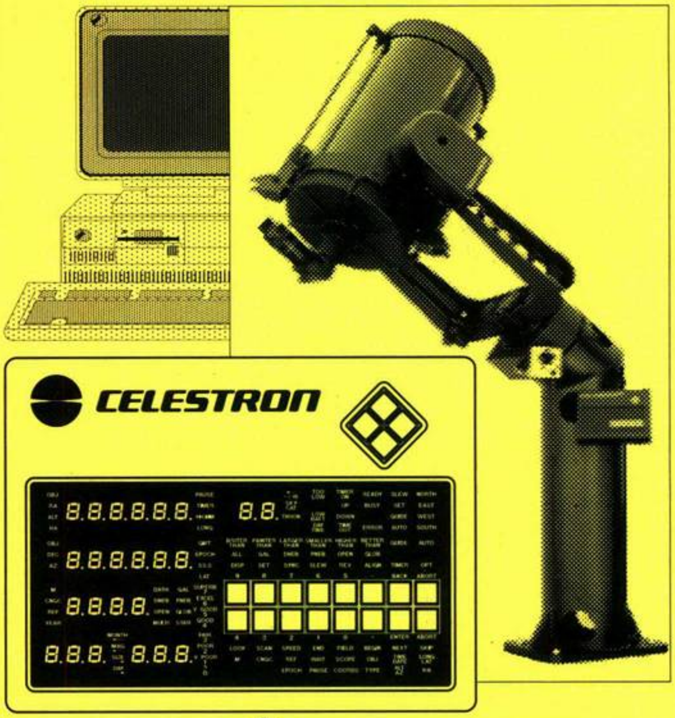

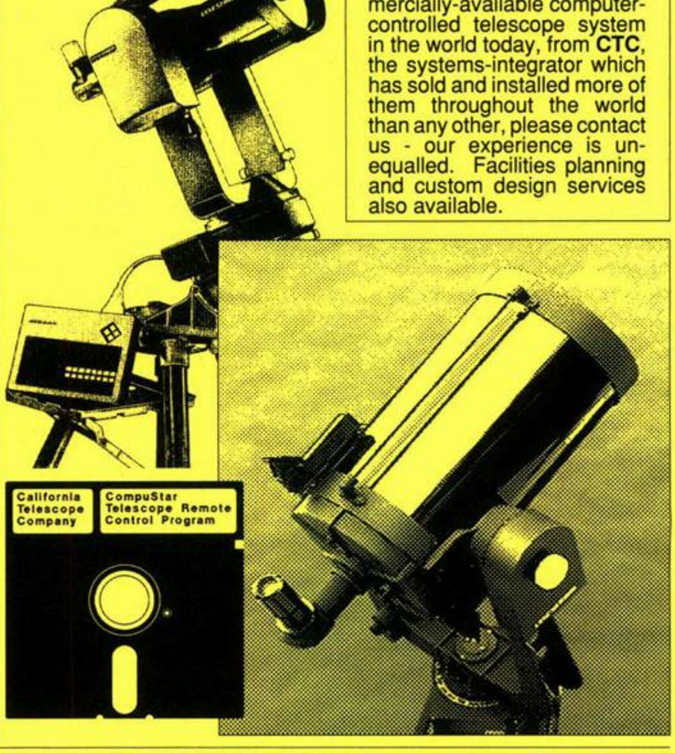
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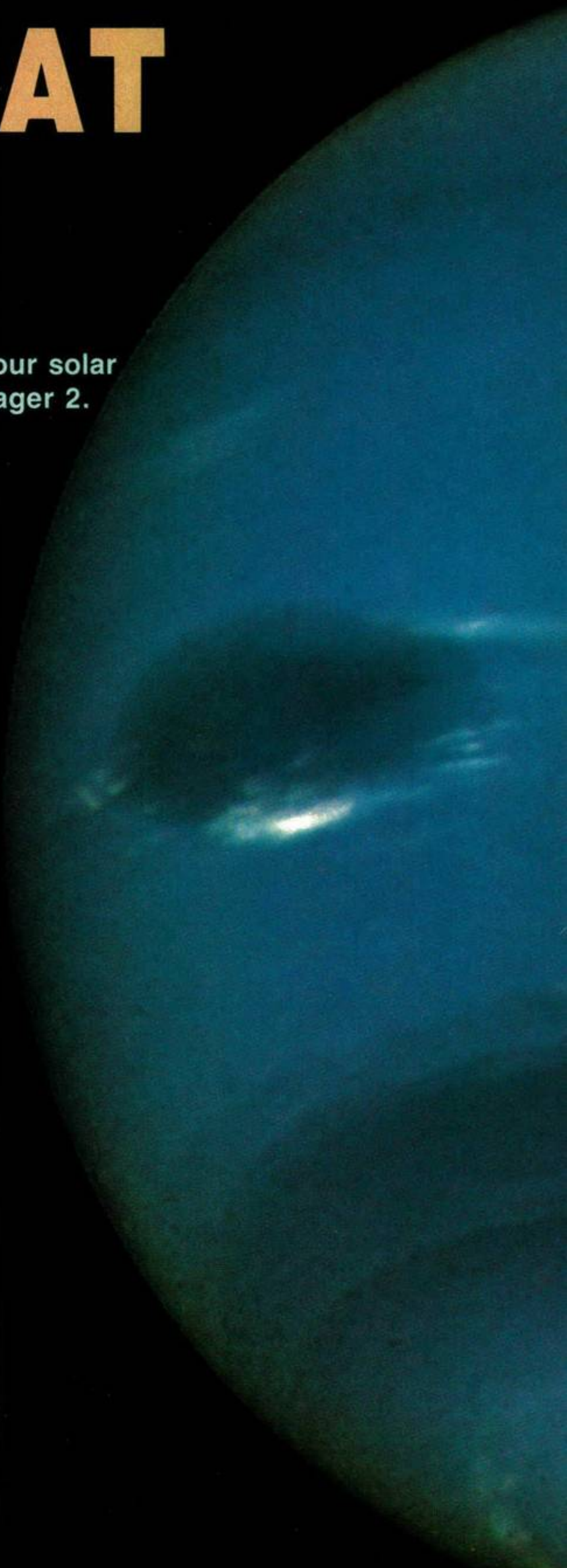
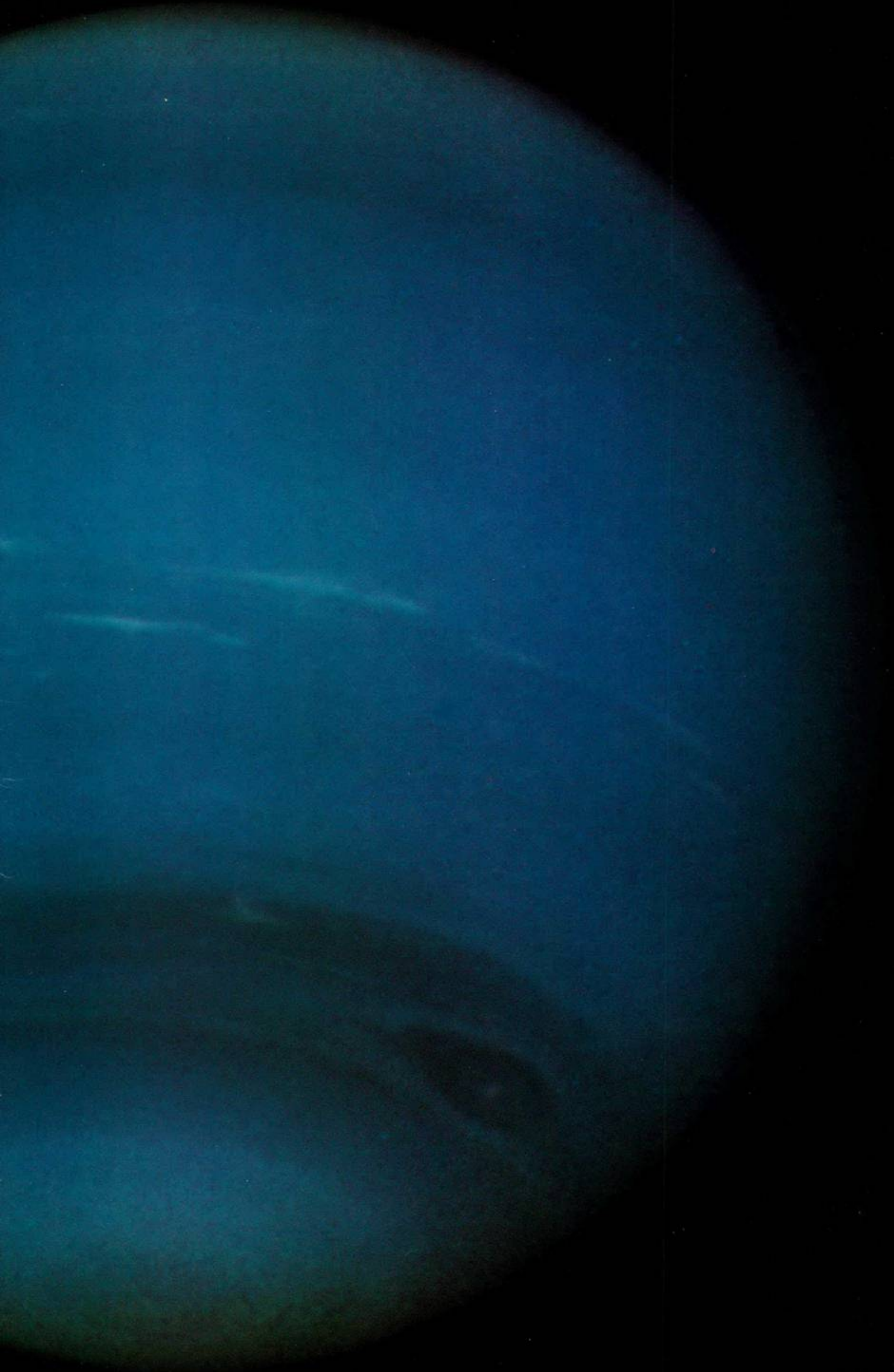
TRIUMPH AT NEPTUNE

We have now traveled nearly to the edge of our solar system, thanks to that intrepid explorer, Voyager 2.

by Richard Berry



ON APPROACH TO NEPTUNE, *Voyager*'s cameras imaged the sunlit face of the enormous blue-green gas giant every few hours to study how Neptune's cloud features evolved over a three-month period. The south pole lies near the bottom of the planet's disk.



Never again will we think of Neptune as a faint blue-green world at the outer margin of the solar system. The vivid pictorial record of a beautiful and dynamic Neptune with clouds, storms, and great wind systems, circled by eight satellites, four rings, and a dust sheet, admits Neptune to the roster of known worlds. Now Triton, only weeks ago a dim satellite of a distant world, also ranks as one of the most exciting objects in the solar system.

During the months prior to *Voyager 2*'s encounter with Neptune, the spacecraft's cameras gradually revealed an active atmosphere with features reminiscent of both Jupiter and Saturn. There were three prominent bright spots and two dark spots.

The larger of the dark features resembled Jupiter's Great Red Spot, so it came to be called the Great Dark Spot. Extending some 12,000 kilometers (7,500 miles) in longitude and 8,000 kilometers (5,000 miles) in latitude, the Great Dark Spot, or GDS, is about the same size relative to Neptune as the Great Red Spot is to Jupiter. The GDS also resembles the Great Red Spot because it lies 21 degrees south of the planet's equator, rotates in a counter-clockwise direction, and is long-lived in the sense that it has persisted at least nine months.

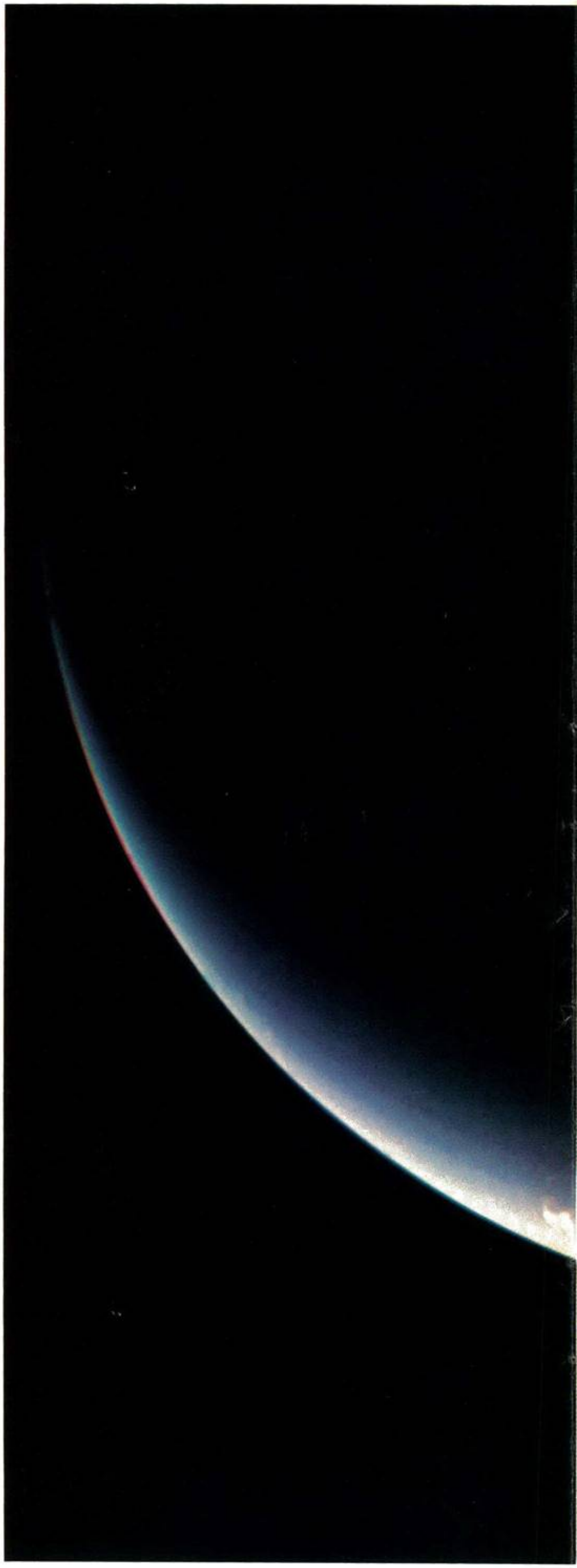
Over the time *Voyager* observed it, the GDS changed appreciably in shape. Over one span of seven 18-hour rotations, the GDS stretched in longitude, spun off a string of dark spotlets, extended to the north, and then stretched out long and thin.

Accompanying the GDS is a bright spot called S1. This bright white cloud lies just to the south of the GDS and is almost certainly the spot Jet Propulsion Laboratory astronomer Heidi Hammel has observed from Earth for several years. Like the GDS, S1 is quite variable in appearance. It grows, shrinks, and moves east and west. Although new white clouds seem to form and move away from S1, it remains just south of the GDS.

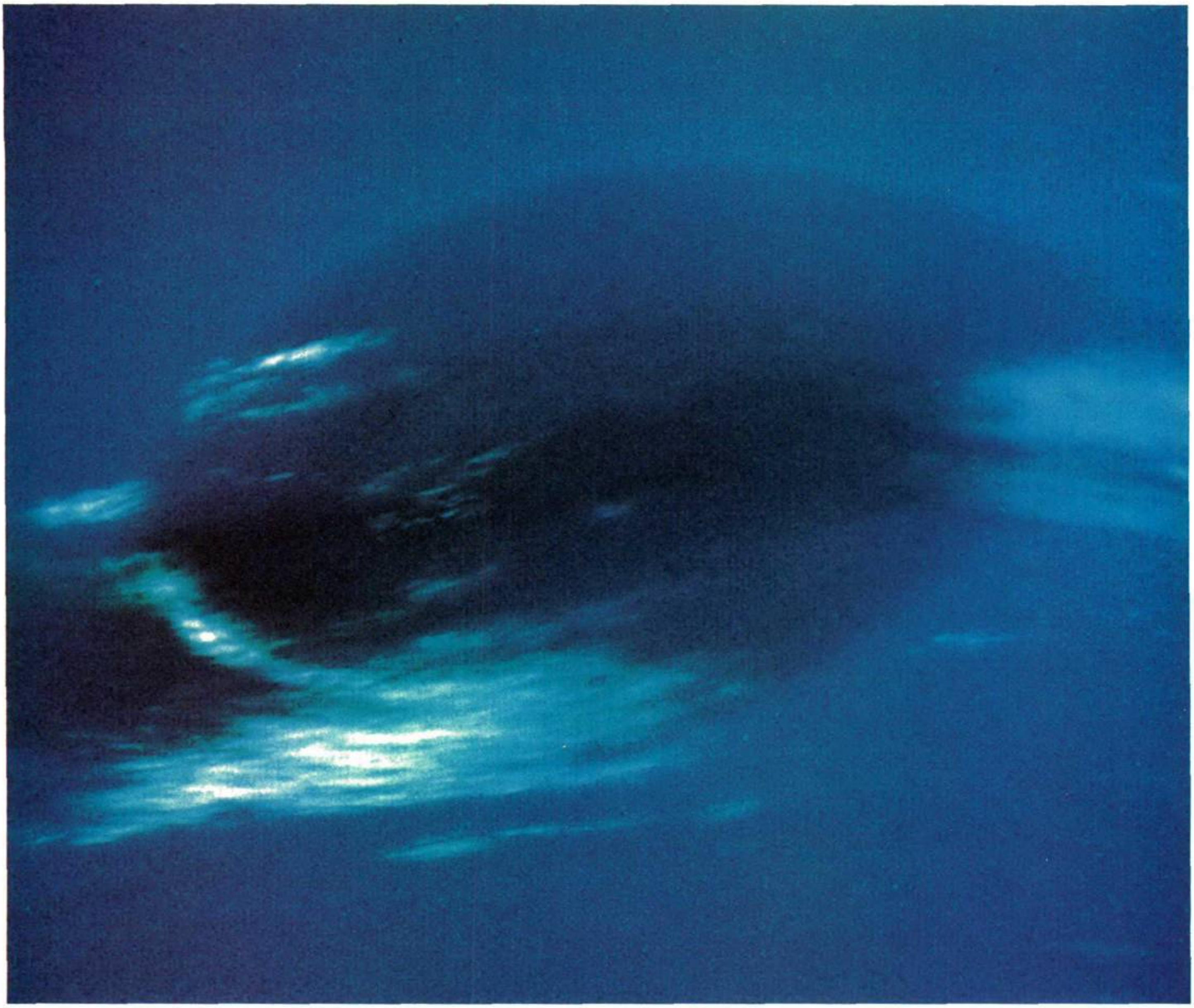
Voyager scientists believe that S1 and the other white clouds near the Great Dark Spot are high altitude clouds, lying roughly 50 kilometers (30 miles) higher than the methane cloud deck of Neptune. The clouds form when winds in the methane-rich hydrogen atmosphere of Neptune are forced to rise over an obstacle such as the Great Dark Spot. When the air rises, methane condenses to form a white cloud. Thus the cloud remains stationary, relative to the GDS, as winds in the atmosphere flow over it.

This causes an extremely frustrating situation for *Voyager* meteorologists, however, because they cannot measure the speed of the winds flowing over and around the Great Dark Spot. To measure the wind speed, the scientists need to track a particular cloud for some time and distance. Neptune's white clouds come and go too fast for the meteorologists to identify and track them.

Relative to the deep interior of Neptune, which rotates in 16 hours, the GDS and spot S1 are moving westward at 325 meters per second. South of the GDS at latitude −41 degrees lies spot S2, nicknamed "Scooter" because it zips around Neptune in 16 hours,



LEAVING NEPTUNE BEHIND after a 100-percent successful encounter, *Voyager* recorded sunlight streaming over a crescent south polar region. Neptune's upper atmosphere is so clear that clouds can be seen circling the planet's south pole in the center of the crescent.



FEATHERY WHITE CLOUDS along the southern margin of the Great Dark Spot change from one rotation to the next. These clouds lie 50 kilometers (30 miles) above Neptune's Great Dark Spot. In this high-resolution view the smallest cloud features are roughly 50 kilometers across.

the same rate as the deep interior of Neptune. The largest of a family of small white spots, "Scooter" may lie over some deep-seated hot-spot in the atmosphere or may result as methane condenses into white clouds in a gravity wave, or wrinkle, in the Neptunian atmosphere.

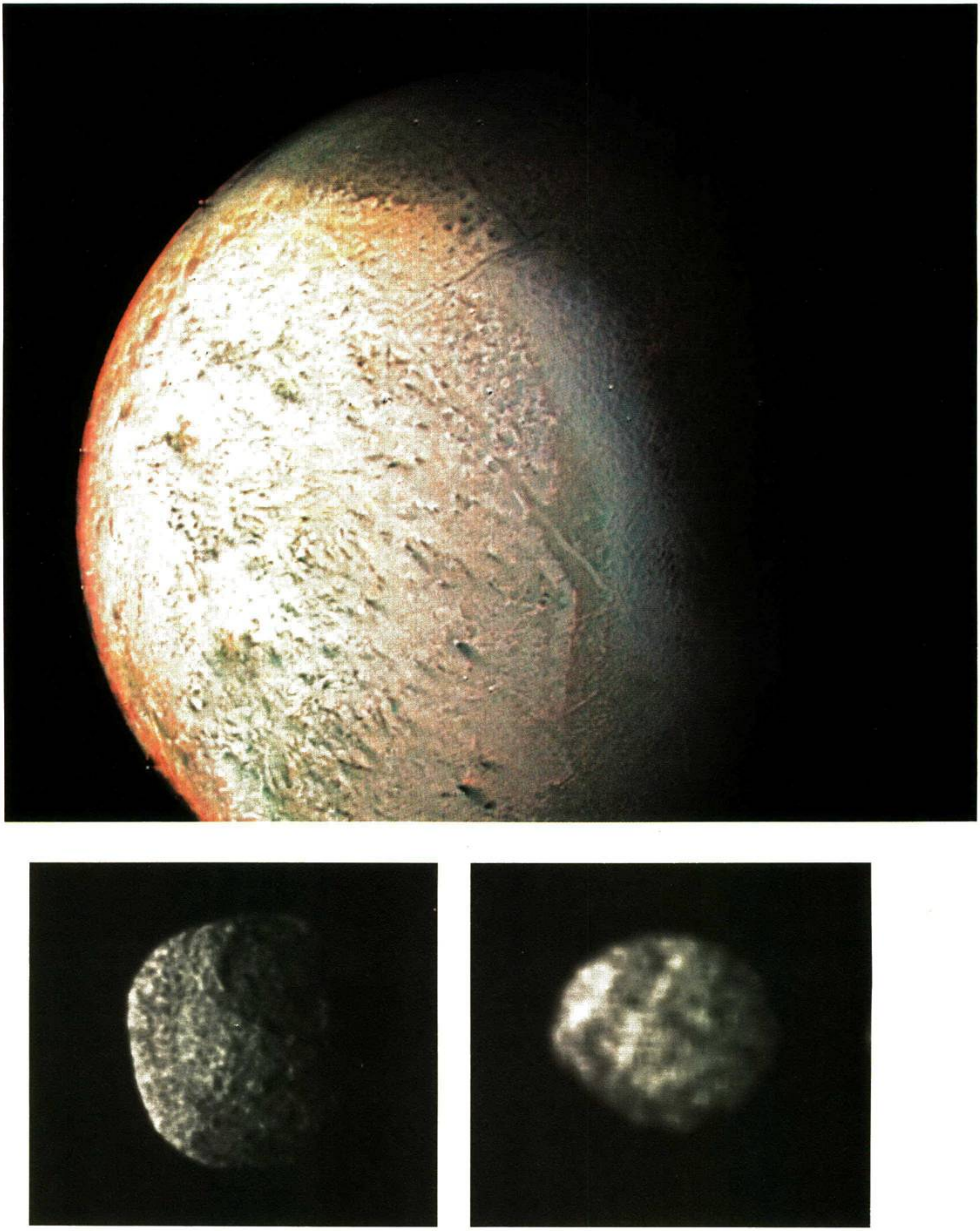
Further south around latitude −51 degrees lies Dark Spot Two (DS2). Smaller than the GDS but as dark or possibly even darker, DS2 sports a distinctive white cloud at its center. This cloud is convective: new cloud material clearly bubbles up from below and spreads out. Like the other white clouds in Neptune's atmosphere, these form and dissipate so rapidly that planetary meteorologists cannot track the winds that drive these clouds.

At latitude −70 degrees a complex of clouds called the south polar feature circled the pole before *Voyager*'s camera. These ever-changing cloud features may nearly wrap around the pole one day and shrink back to a short arc a few days later. While the structure persists, the clouds that make up the south polar feature do not last long enough for the meteorologists to identify and track their winds.

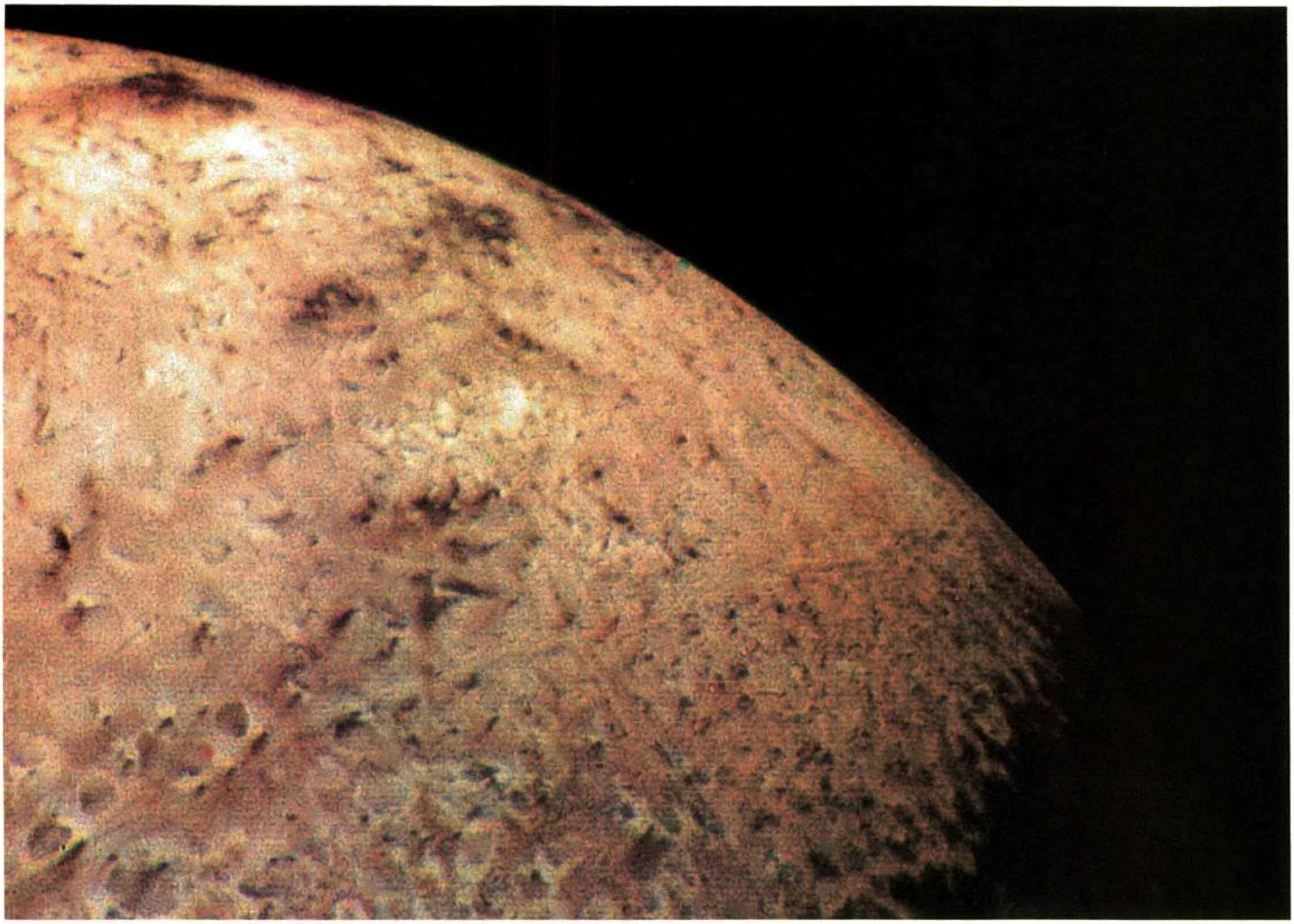
As *Voyager* approached Neptune, mission scientists expected to find partial rings, or ring arcs, rather than complete rings. The first images that showed ring structures appeared to support this. However, as *Voyager* moved closer to Neptune, long-exposure ring search images established that the ring arcs were simply the brightest segments of a complete ring, 1989N1A. Furthermore, a second complete ring, 1989N2A, lay inside the first. Images taken looking back at the planet after closest approach revealed a third diffuse ring some 2,500 kilometers (1,500 miles) wide and a broad sheet of dust extending inward from a diffuse fourth ring.

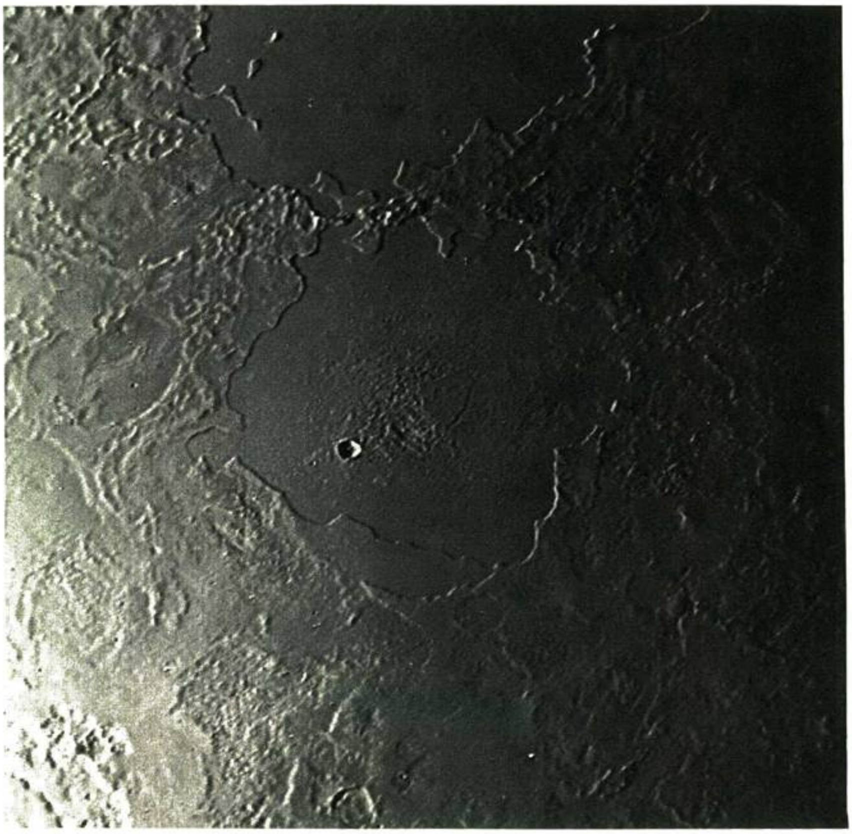
Rings 1989N1A and 1989N2A orbit very near satellites 1989N4 and 1989N3, respectively. These satellites give theoreticians something to hold the ring particles at the correct distance from Neptune, but they do not explain why ring material was confined to the bright, dense segments *Voyager* observed.

High-resolution long-exposure frames of the bright segments of ring 1989N1A soon suggested an explana-



FROSTY TRITON (top) has an active and highly reflective surface that contrasts sharply with the dark, heavily cratered surfaces of the newly discovered moons 1989N1 and 1989N2 (above). Regions that appear bluish in this false-color image are the brightest areas of Triton.





POLAR DEPOSITS and ice volcanism dominated *Voyager*'s view of Triton. The polar cap (above) tends to be pinkish in color and shows irregular patterns that could be hills or frost features. Ice lakes (right) suggest a complex geological history and tidal heating of this frigid world.

tion. Within the bright segments were dozens of tiny, unresolved points of light, possibly moonlets no more than 10 to 15 kilometers (6 to 9 miles) in diameter embedded within the ring. The ring itself was too narrow to show as more than a line.

The stellar occultation experiment shed more light on the ring structure. As the star Sigma Sagittarii went behind the bright ring segment, the photopolarimeter monitored the brightness of the star. The profile of the transmitted light showed a dense core 17 kilometers (10 miles) wide with a much thinner component extending some 50 kilometers (30 miles) toward Neptune.

As *Voyager* crossed the ring plane, the plasma-wave experiment showed another entirely different type of ring. Both inbound and outbound, the plasma-wave detector recorded the impacts of millions of tiny, dust-sized particles. For two hours *Voyager* flew through the particles and at the ring plane itself flew through a blizzard of impacts peaking at some 300 per second.

The observation implies that outside Neptune's visible rings lies a disk of dust some 10,000 kilometers (6,000 miles) thick. The disk is enveloped in a tenuous halo of dust that extends at least one Neptune radius above and below the ring plane. *Voyager* detected a similar dust disk during its encounter with Saturn.

Everyone expected *Voyager* to find new satellites, and they were right. *Voyager* discovered six new moons and imaged two of them at high resolution. The spacecraft also photographed Nereid, a previously known satellite that orbits far from Neptune, at low resolution.

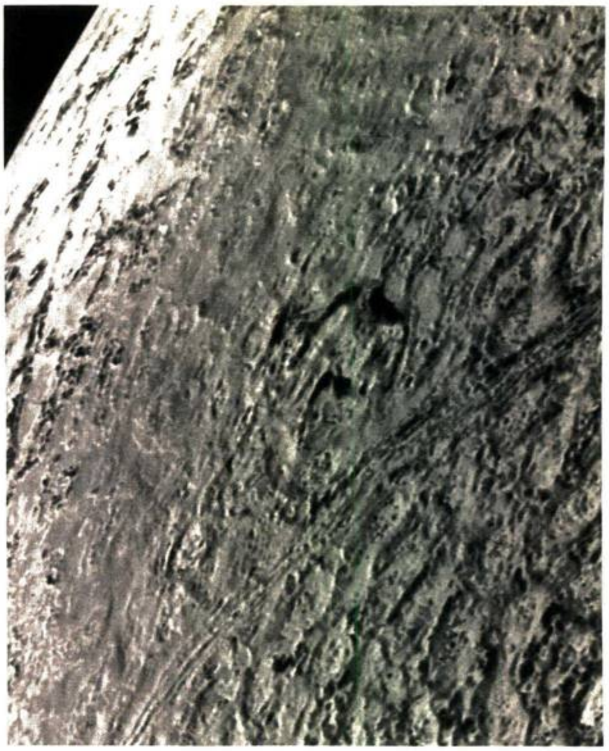
The outermost of the new satellites is 1989N1, which orbits the planet with a period of 27 hours. Roughly 400 kilometers (250 miles) in diameter, this small object is slightly but distinctly out of round. This suggests that it is frozen hard and has never melted or softened. Its surface is very dark, reflecting only 6 percent of the sunlight that falls on it, and it appears to have been cratered during its history.

The next satellite inward is 1989N2, an irregular body some 210 by 190 kilometers (130 by 120 miles), or about half the size of 1989N1. Reflecting 5 percent of the light that strikes it, the satellite shows numerous craters between 30 and 50 kilometers (20 and 30 miles) wide. It orbits Neptune with a period of 13.3 hours.

1989N3 and 1989N4 each accompany one of the planet's rings. These satellites orbit just inside the associated ring and are closer to the planet than the ring. N4, at 160-kilometers (100 miles) diameter, is the larger of the two moons and accompanies ring 1989N1A with its bright "ring-arc" segments. N4, however, cannot by itself explain the clumping of ring material. N3 orbits 2,000 kilometers (1,250 miles) inside ring 1989N1B and is roughly 140 kilometers (90 miles) in diameter.

Satellites 1989N5 and 1985N6 were discovered in close-encounter search images. Both are small — with diameters of 90 and 50 kilometers (55 and 30 miles), respectively — but N6 differs from every other new satellite because its orbit is inclined some 4.5 degrees to the plane of Neptune's equator. The other new moons deviate less than 1 degree; Triton is inclined by 20 degrees.

The most exotic world *Voyager* revealed in the outer solar system turned out to be Neptune's large satellite Triton. As *Voyager* approached Triton, the cameras showed a dazzlingly white world with a polar cap of frozen nitrogen and land forms so exotic and complex that they defy immediate interpretation and will require years to fully understand.



STRANGE PATTERNS characterize the landscape of Triton's southern polar cap. Planetary astronomers think this terrain is geologically young because there are very few impact craters among the many circular pits and depressions.

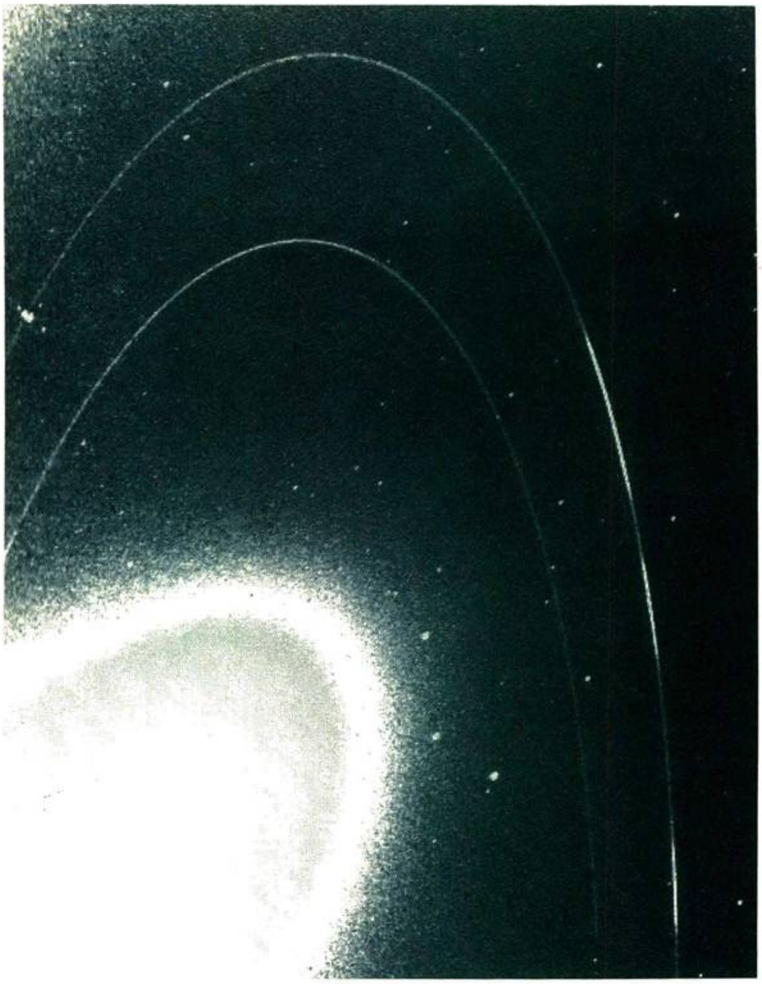
On its approach trajectory *Voyager* came from the south. From far away, the cameras were well placed to show Triton's vast bright polar cap. Covering most of Triton's southern hemisphere, the ice reflects nearly all of the light that strikes it. The surface is exceedingly cold, around 37 kelvins, which is below the freezing point of nitrogen gas. Only near the equator does the polar whiteness darken to reflectances as low as 50 percent.

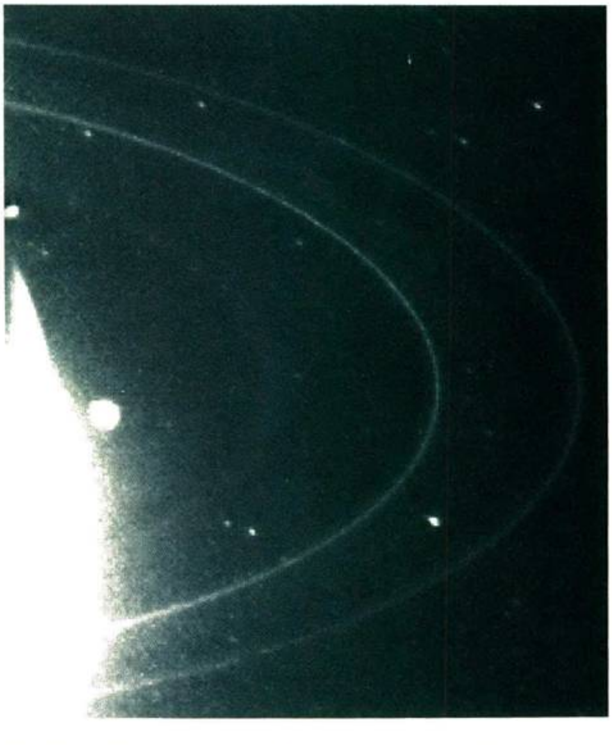
At high resolution *Voyager*'s cameras showed that Triton's polar cap is in the process of breaking up as the satellite moves toward the height of its southern hemisphere summer. The interior of the ice-covered region shows small, darker regions, where the nitrogen ice cover may have evaporated, and numerous dark streaks that resemble plumes from vents or geysers.

Preliminary crater counts show that Triton probably has a very long geological history that stretches back at least 3 billion years. The geological activity that shaped the surface took a significant time — perhaps 1 or 2 billion years — and the satellite has been much less active for perhaps another 2 billion years. However, Triton has no ancient heavily cratered terrains that date back to the time of its formation; these have been erased by an exotic ice-based form of volcanism or the wholesale melting of the object.

Within a day of the flyby, planetary geologists had characterized several different terrain types but could not pinpoint their origins or histories. Near the margin of the polar cap, there are old regions that showed as many craters as the oldest maria on Earth's Moon, implying an old surface. These regions lay adjacent to mysterious, irregular dark patches that may have lost their nitrogen ice cover within the last year or two.

Around the equator stretch large expanses of rela-





RINGS CIRCLE NEPTUNE in these long-exposure images taken after closest approach. The outermost ring, called 1989N1A, contains three bright ring arc segments. Bright 1989N2A is rich in dust. A diffuse inner ring and a broad disk of dust with a bright outer edge complete Neptune's ring system.

tively young, uncratered "cantaloupe" terrain. Like the melons, these surfaces are covered with shallow linear ridges with pockmarks between them. In the north there are large areas where "volcanic" flows of water, possibly mixed with ammonia, methane, and dissolved nitrogen, have created lakes and calderas. Some places show evidence of repeated flows and retreats with multiple flow fronts and steps in the terrain, while other areas have simply been flooded over.

The most complex surfaces occur on the margins between the polar cap and the young equatorial volcanic and cantaloupe terrains. Along the edges of the polar cap, new blue-white frost overlays old land forms, and the old polar cap ice has melted wherever the surface slopes toward the Sun.

Some of Triton's most interesting features are the dozens of dark plumes, all of which point roughly northeast. These may result from wind-scour in the lee of hills or from gentle eruptions of fine dark material such as radiation-darkened methane from the interior. Alternatively, the plumes could mark rapid expansion of subsurface nitrogen deposits as the polar ices evaporate because of the oncoming Tritonian southern summer.

Triton's atmosphere is quite thin. At the surface the pressure is only 10 microbars. It is composed almost entirely of nitrogen with a trace of methane gas, according to data taken when Triton occulted the star Beta Canis Majoris. The nitrogen envelope extends at least 800 kilometers (500 miles) above the surface of Triton, but the methane lies much closer. Images of Triton's limb show a haze layer in the atmosphere extending some 25 kilometers (15 miles) above the surface. The haze could result from the freezing of methane gas or the interaction of sunlight with methane to form an aerosol of hydrocarbon particles.

Triton's exotic surface and its complex geological history will take many years to unravel. The behavior of the materials that make up Triton are not well understood at the temperatures and pressures that exist on the surface and in the interior of Triton.

As *Voyager* penetrated the space around Neptune, its magnetometer and charged-particle experiments measured the magnetic field strength and magnetosphere of the planet. The surprising result was that Neptune looks like Uranus magnetically. Neptune's magnetic field is tipped at least 50 degrees relative to the planet's axis of rotation, and it appears to be offset from the center of the planet.

Before this discovery, astronomers tended to regard Uranus' unusual tipped and eccentric magnetic field as an anomaly, perhaps a magnetic field reversal caught in the act. However, it is unlikely that Neptune would also have been observed at such a unique time, so the problem of explaining the magnetic fields of the two planets cannot be avoided.

Understanding the magnetic field is crucial because it is the only direct link scientists have with the deep interior of a planet where the field originates. The rotation of the magnetic field, measured as 16 hours 3 minutes, also has profound implications for atmospheric scientists. They must now explain the rapid westward motion of features like the Great Dark Spot relative to the core. Even more important, they must explain how a planet as far from the Sun as Neptune gets the energy to drive its dynamic atmosphere. Working on these problems will ultimately lead to a better understanding of not only Neptune, but of the whole solar system. ☐

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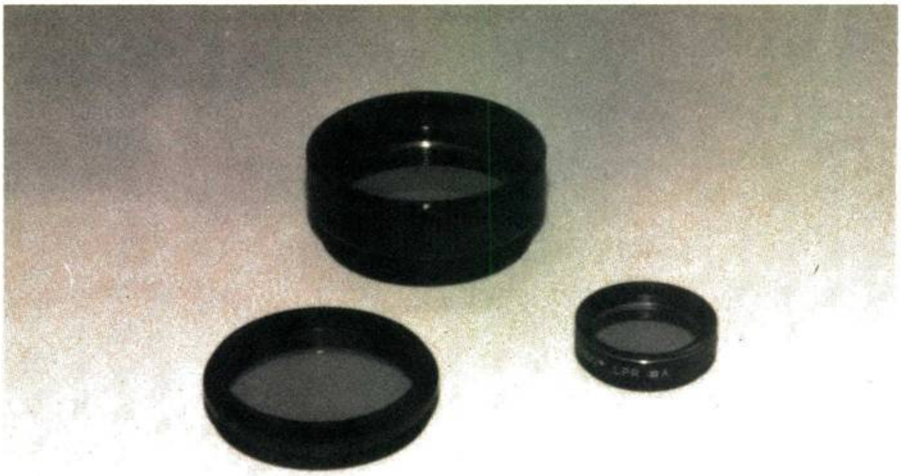

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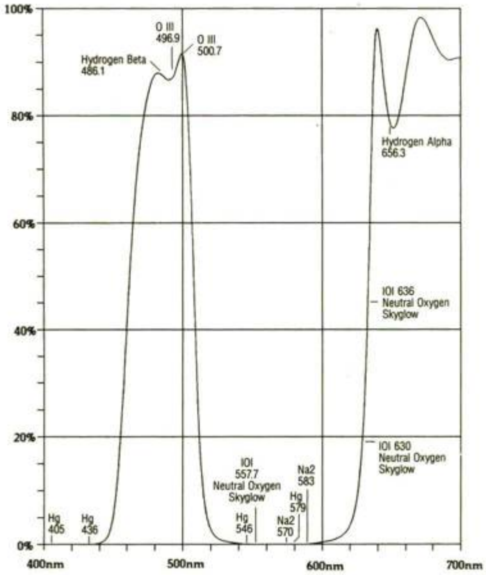

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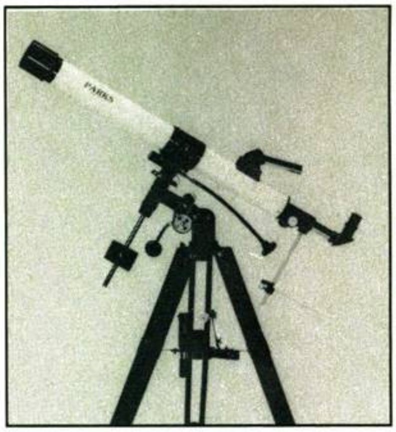

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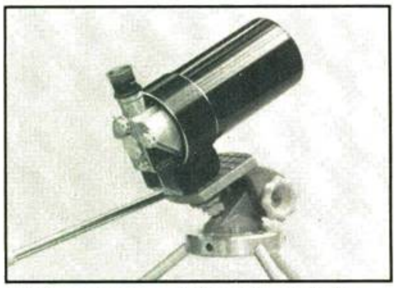

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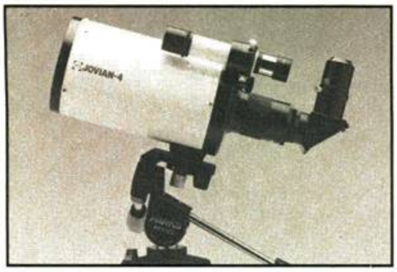

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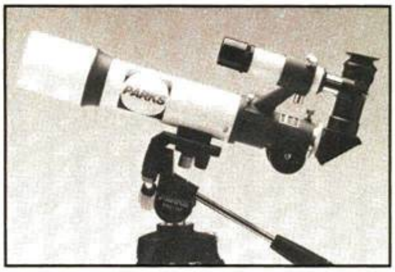

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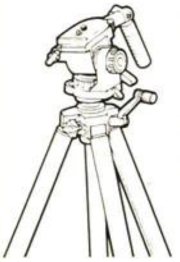

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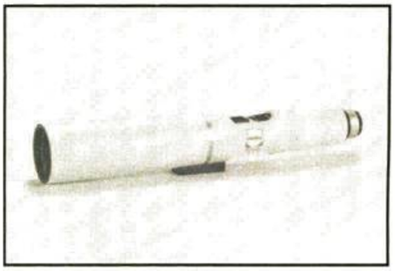

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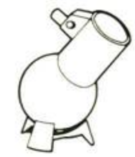

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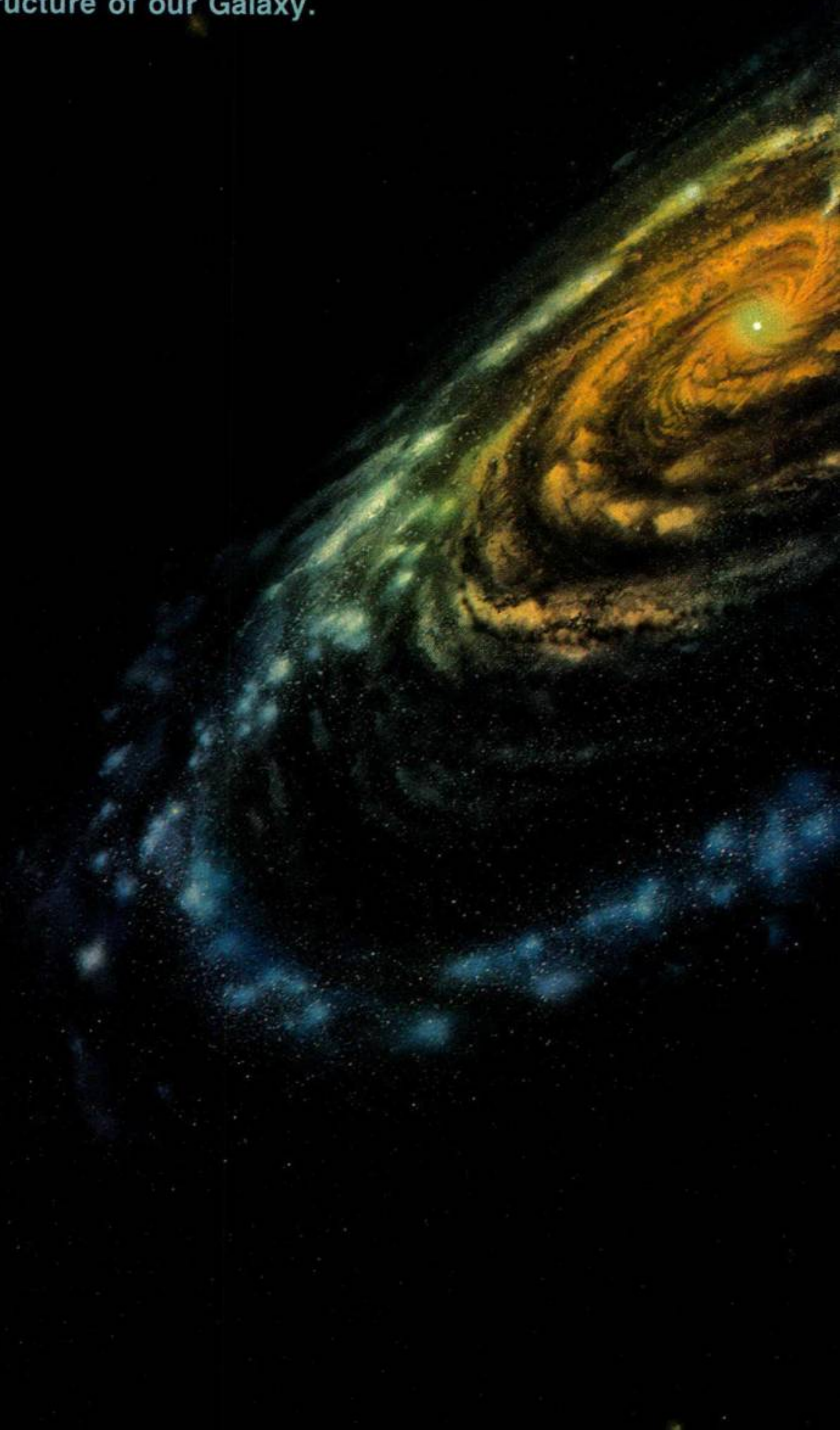
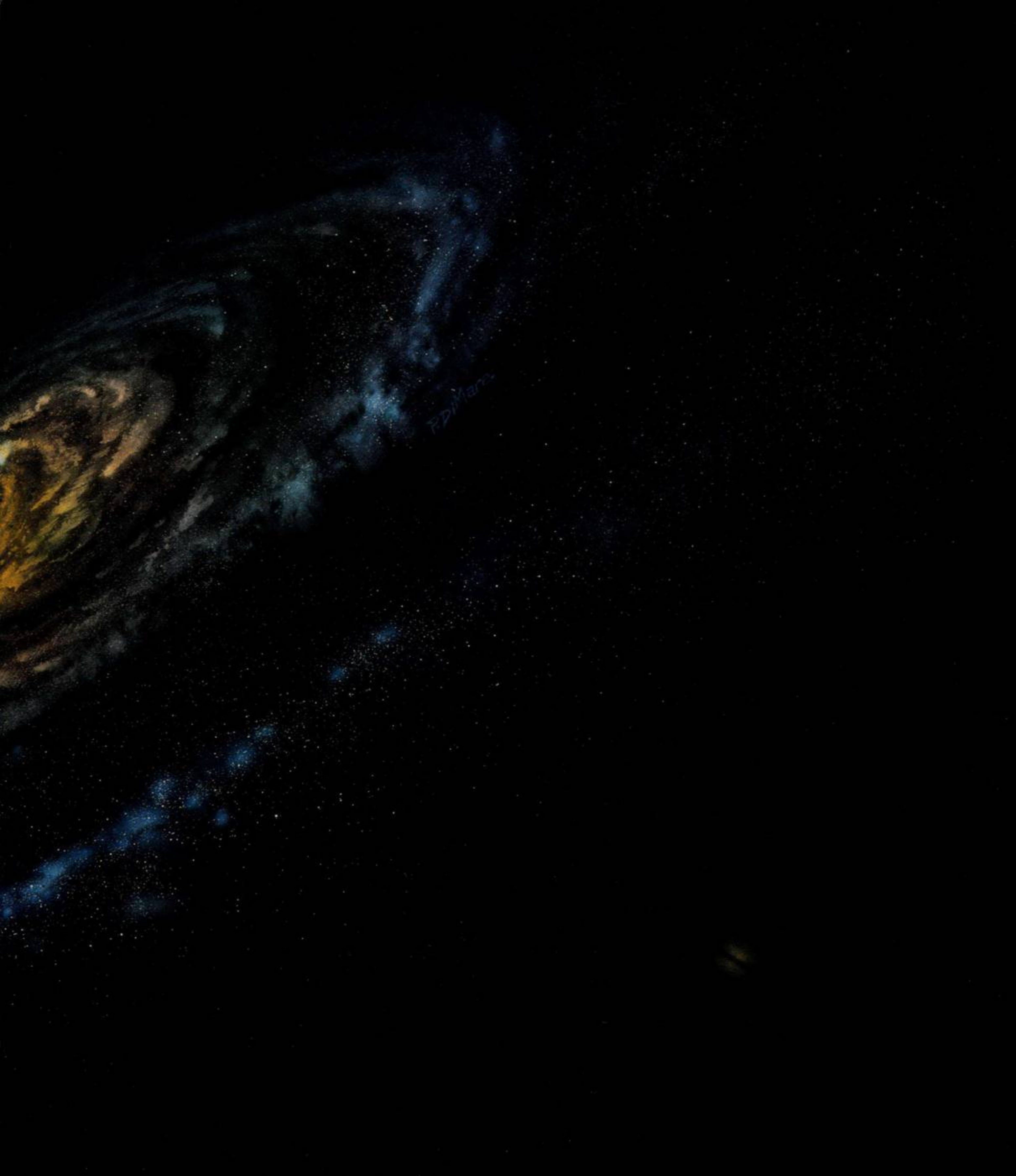
Unveiling the Hidden Milky Way

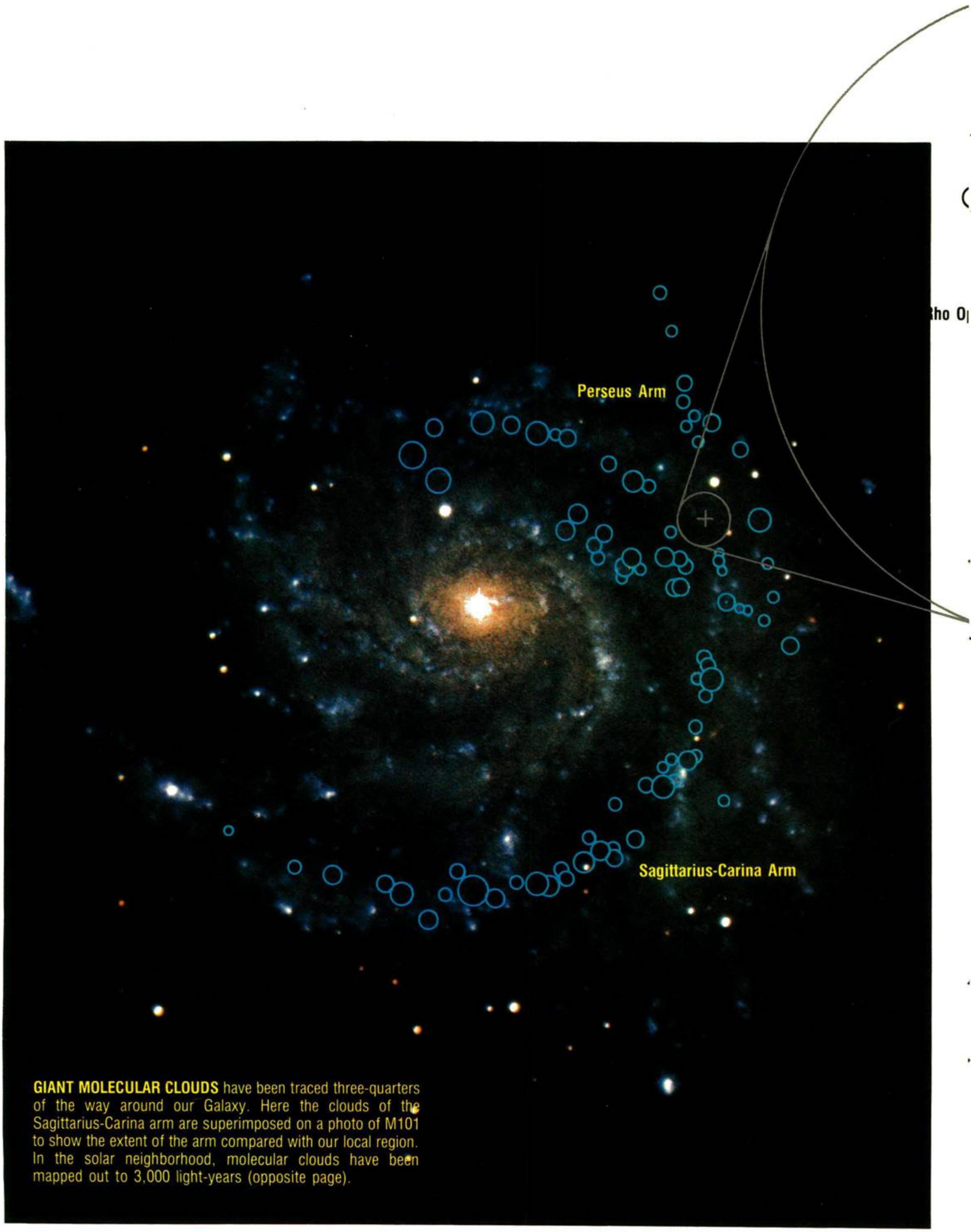
Radio astronomers peering through the dust of the galactic plane are tracing out the spiral structure of our Galaxy.

by E. Samuel Palmer

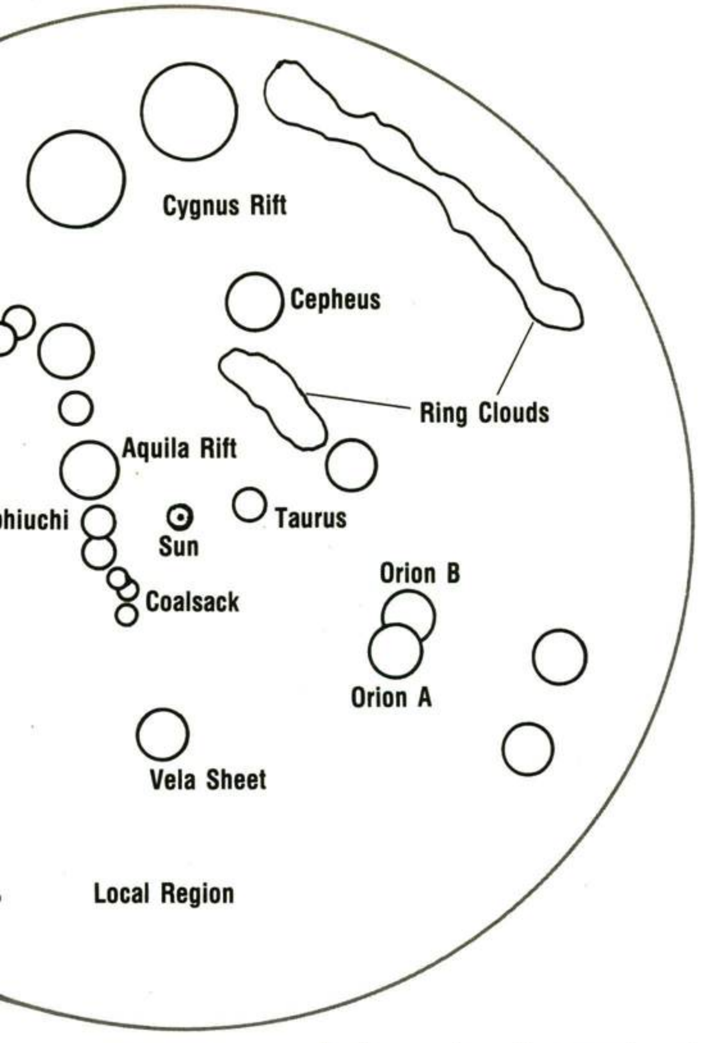




OUR GALAXY, as revealed by molecular-cloud mapping, is similar to most spiral galaxies in structure.


Perseus Arm
Sagittarius-Carina Arm
ho O

GIANT MOLECULAR CLOUDS have been traced three-quarters of the way around our Galaxy. Here the clouds of the Sagittarius-Carina arm are superimposed on a photo of M101 to show the extent of the arm compared with our local region. In the solar neighborhood, molecular clouds have been mapped out to 3,000 light-years (opposite page).



Any stargazer looking at the Milky Way through binoculars on a dark, moonless night is struck by the vastness of the heavens, by the sheer number of stars. Yet even more incomprehensible is the fact that the visible stars of the Milky Way are only our nearest neighbors: Most stars in our Galaxy are hidden from view because the Sun and our solar system are located precisely within a thin plane of opaque interstellar dust extending throughout the galactic disk.

Observations at infrared and radio wavelengths, which are capable of "seeing through" much of this dust, tell us that the disk of our Galaxy is about 100,000 light-years in diameter. Fortunately, the dust layer is only a few hundred light-years thick. Viewed edge-on, our own Galaxy would look like the spiral galaxy NGC 4565 — a thin needle of light with a band of dust dividing its plane. Viewed face-on, our Galaxy would look like M101, which has many dust lanes running along bright spiral arms. Perpendicular to the disk, the thin dust absorbs only 1 percent of incoming light, allowing us to see far beyond our Galaxy into deep space. Toward the inner Galaxy, however, the dust blocks our view entirely.

The nearest dust clouds stand out in relief against the stars, sometimes prominently, sometimes subtly, depending on their size and distance. The Aquila Rift, for example, is caused by a cloud only 600 light-years away that obscures more than 100 square degrees of sky.

Optical astronomers have mapped what look like small segments of local arms of the Milky Way by tracing objects such as planetary nebulae, ionized hydrogen clouds (H II regions), and associations of young, hot O- and B-type stars. A few of these objects — visible at much greater distances in those rare directions when they are not blocked by dust — provide hints of spiral arms.

Though a general picture of our Galaxy has emerged over the years, the details of galactic structure have, until recently, remained elusive because of our inability to penetrate interstellar dust.

The 21-Centimeter Line

In 1951, radio emission from interstellar atomic hydrogen was detected at a wavelength of 21 centimeters. This discovery inaugurated a new era in the study of galactic structure. Roughly 75 percent of the matter in our Galaxy is in the form of stars; the rest is interstellar matter, which, like the stars made from it, consists of about 90 percent hydrogen atoms, 10 percent helium atoms, and less than 1 percent everything else, including the obscuring dust. The hydrogen in interstellar matter is easy to observe when it is in its atomic form (H) because it emits radio waves at 21 centimeters.

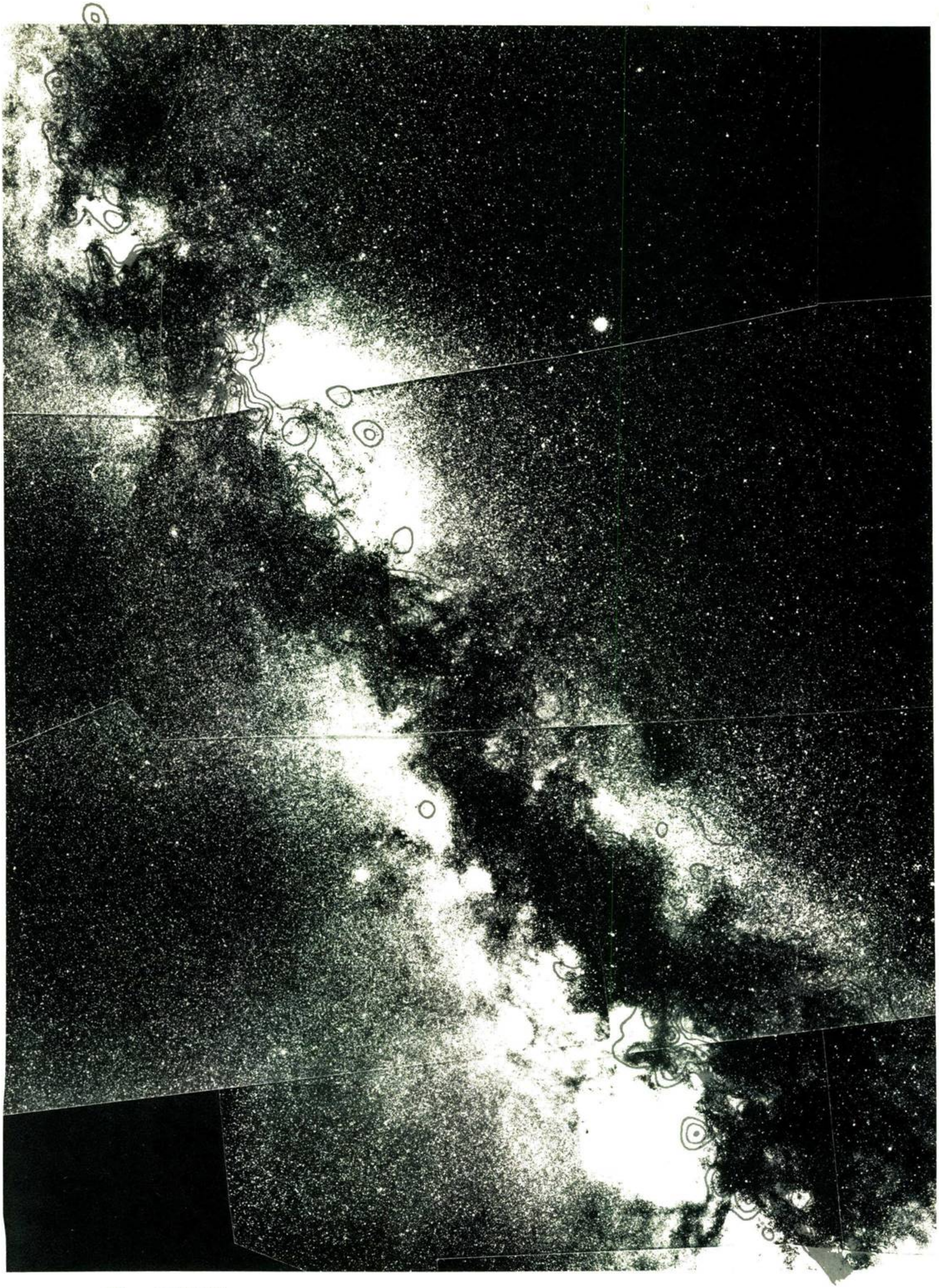
The strength of this emission provides a measure of the amount of atomic hydrogen in a given direction in space. The precise frequency of the emission we receive provides a measure of the atomic hydrogen's line-of-sight motion (its radial velocity), which is calculated using the Doppler effect. According to the Doppler effect, emission from matter moving away from us is "red-shifted" to longer wavelengths, while emission from matter moving toward us is "blue-shifted" to shorter wavelengths. Such radial velocity information is essential for working out the structure of our Galaxy. (See "How Astronomers Map Our Galaxy," page 39.)

Two features of the 21-centimeter observations combine to solve the problem of penetrating the obscuring dust in the clouds. First, the dust that absorbs the visible part of the spectrum is transparent to radio waves. Second, because gas clouds at different distances generally have disparate motions, their spectral line emissions are Doppler shifted to different wavelengths. Hence, a foreground cloud doesn't block radiation from a background cloud, and because the clouds radiate at different wavelengths, they can be distinguished even when they lie in the same direction.

The first real look at the Milky Way's large-scale spiral structure occurred in 1958 when astronomers observing from Leiden, The Netherlands, and Sydney, Australia, produced a 21-centimeter map of cloud features. Two limitations, however, concealed the important fine structure. First, in directions toward the galactic center and anticenter, matter has most of its motion nearly at right angles to our line of sight so its radial velocity is nearly zero. Thus, in these directions, clouds at different distances can't be distinguished by Doppler shift. Second, there can be too much of a good thing; there is so much hydrogen that separating the overlapping features can be like trying to tell where one tree ends and the other begins in a thick forest.

Carbon Monoxide Observations of Molecular Clouds

A third limitation, never anticipated by astronomers at the time the 21-centimeter map was made, is that as much as half of the hydrogen in the Galaxy's disk is molecular. When interstellar gas condenses under gravity into dense clouds, the hydrogen atoms combine to form hydrogen molecules (H_2), which are invisible to radio telescopes. Hydrogen molecules have no spectral lines at radio frequencies. This means that the radio sig-



nals from hydrogen are weak in the most interesting places: dense interstellar clouds, the nurseries where stars are born.

The trick to making the invisible visible is to observe something that can trace the invisible. Where conditions favor the formation of hydrogen molecules, other elements also form molecules that *are* easily detectable. The next most abundant interstellar molecule after hydrogen, carbon monoxide (CO), emits a spectral line at a wavelength of 2.6 millimeters.

Carbon monoxide makes the molecular matter visible to a radio telescope. Left alone, a carbon monoxide molecule remains in its lowest energy level, or ground state, with no extra energy to radiate. In a hydrogen cloud, however, the carbon monoxide molecule is energized by collisions with the abundant hydrogen molecules, which causes it to rotate. The carbon monoxide molecule rids itself of the extra rotational energy by emitting photons. The wavelength most commonly emitted by these photons, 2.6 millimeters, corresponds to the difference in energy between the carbon monoxide molecule's first rotational energy level and its lowest rotational energy level. Because hydrogen molecules stimulate carbon monoxide molecules to radiate at detectable wavelengths, the carbon monoxide emission alerts astronomers of the presence of molecular hydrogen gas.

This has important results for discerning structure in the Galaxy. The study that my colleagues and I made of the interstellar gas complements the 21-centimeter work because we looked at the "other half" of the interstellar medium — the molecular hydrogen. This other half, however, is not just more of the same stuff. Unlike the atomic gas, which is widely distributed, the molecular gas is concentrated into well-separated giant clouds, each containing from 100,000 to 10 million solar masses of material and measuring hundreds of light-years across. These giant molecular clouds are the sites of star formation, and regions of star formation are the markers of spiral structure in a galaxy. Like the bright H II regions in M101, the molecular clouds, at radio wavelengths, trace spiral arms of our Galaxy like beads on a string.

Mapping a Cloud

A radio telescope, unlike an optical telescope, does not form images directly. Instead, a single receiver at the focus of the antenna is used to build up an image point by point on the sky. The receiver system we used on the carbon monoxide telescope is the equivalent of 256 radios tuned to adjacent channels simultaneously receiving power across a band of frequencies. When we plot the signal strengths received across all the channels, the resulting spectrum is a measure of the total amount of carbon monoxide in a given direction, including emission at different wavelengths corresponding to clouds with different radial velocities. The first step in building a complete model of the Galaxy is to determine the radial velocity of each cloud we can detect. From the radial velocities, we can find distances to the clouds.

After we collect observations over a region, we process them in a computer to produce a three-dimensional array of data showing the amount of carbon monoxide emission for each galactic longitude, latitude, and radial velocity. Usually these data are presented as sets of two-dimensional maps. While the longitude-latitude map corresponds to an ordinary picture of the sky, the longitude-velocity map separates clouds in the same direction and provides information for estimating their distances.

The Carbon Monoxide View

The photo on the opposite page shows a plot of the local molecular clouds in the northern Milky Way superimposed on the optical view. (Local clouds are identified by their low radial velocities, i.e., they move more or less with the Sun in our part of the Galaxy.) A chain of large, dark nebulae, known as the Great Rift, is clearly delineated in the mosaic by the outlines of the carbon monoxide emission between the constellations Cygnus and Sagittarius. The composite carbon monoxide map combines twelve clouds at distances ranging from 600 to 6,000 light-years. The Great Aquila Rift, prominent between 30° and 40° longitude, is actually a relatively small cloud that looks big on the sky because it lies close to us.

The Rosette Nebula in Monoceros (page 40) is a photogenic example of a star-forming region. It lies about 5,000 light-years from the Sun. This cloud of ionized hydrogen (H II region) is about 100 light-years across and contains some 6,000 solar masses of material. The 300 solar-mass cluster of young, hot O- and B-type stars in its center recently formed from this cloud, and ultraviolet light from the brightest of these stars excites the nebula to glow with the red light of hydrogen.

The contours show the Rosette region mapped in carbon monoxide. This larger molecular cloud, which fits the ionized hydrogen cloud like a glove, is the parent of the Rosette and contains about 100,000 solar masses of material. After matter collapses to form stars, the radiation from the new stars dispersed the molecular cloud to reveal both the new stars and an H II region, which comprises the last remnants of that part of the original molecular cloud. Gas driven from the H II region back into the parent cloud may precipitate the next generation of stars. From what astronomers understand of this stellar distilling process, only a small portion of the mass of a cloud is converted into stars at any one time. The rest of the mass gravitationally collects again to form new clouds.

Spiral Structure

This close correlation of molecular clouds with star formation allows galactic structure to be studied with carbon monoxide observations. The most dominant structure seen in other spiral galaxies are the "arms," arcing bands of gas and dust accentuated by bright regions of newborn stars. Where there are signs of star formation, there are also dense molecular clouds, as in the case of the Rosette Nebula.

The analysis of the positions and radial velocities (distances) of carbon monoxide from both the Northern and Southern Hemispheres has made it possible to map a continuous spiral arm three-quarters of the way *around* our Galaxy. (The diagram on page 34 shows this arm, called the Sagittarius-Carina arm, as traced by molecular clouds.) The carbon monoxide clouds trace the spiral arm just as star-forming regions trace the arms for M101.

CARBON MONOXIDE EMISSION traces molecular hydrogen gas in dust clouds in the dark cleft known as the Great Rift, which extends from Cygnus (upper left) through Aquila (center) and into Serpens (lower right).

A close-up of the solar neighborhood out to 3,000 light-years appears in the inset on page 35. Here the clouds are labelled with the name of their optical counterparts, which is the cloud itself in some cases (for example, the Coalsack and the Aquila Rift). Our view of the Milky Way from the Northern Hemisphere is centered on galactic longitude 125° — dead into the local clouds!

Efforts to map the intensity and distance of carbon monoxide molecular clouds in the Milky Way's inner spiral arms culminated in 1988 when Thomas M. Dame, the project scientist in the carbon monoxide program, assembled data from seventeen separate Northern and Southern Hemisphere surveys. To produce a final composite survey with both uniform resolution and sensitivity, Dame first smoothed the higher resolution data to the same resolution as data for the relatively empty regions surveyed in a half-degree resolution scanning mode. Similarly, he adjusted the sensitivity levels and coordinate grids to the same scales. The data represented 31,000 scans covering 7,700 square degrees on the sky (500,000 points at full resolution).

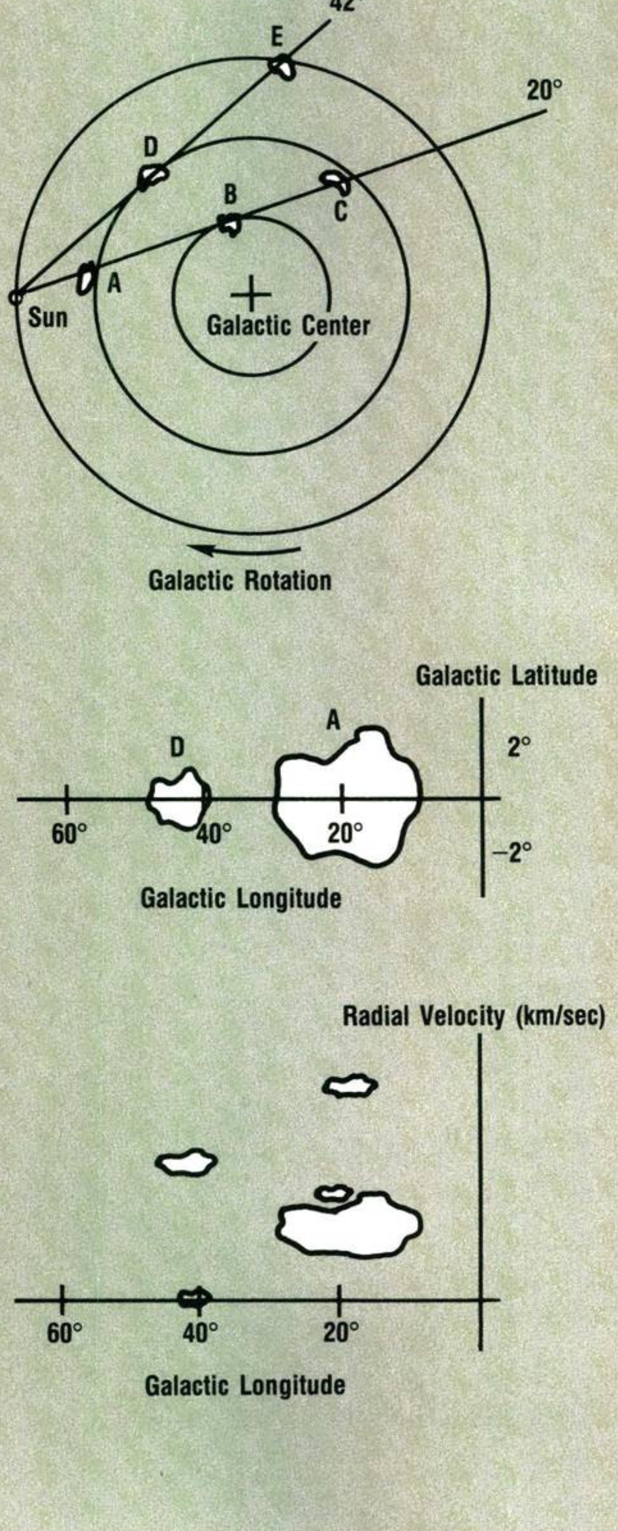
Part of Dame's two-part map covering 180° in galactic longitude appears on the opposite page. The top panel is the longitude-latitude map of carbon monoxide-emission intensity. Carbon monoxide is most intense within a region of about 60° of the galactic center, clearly placing the Sun at the outer reaches of the inner molecular ring. The map also reveals apparently large clouds at high galactic latitudes (the Rho Ophiuchi and Lupus clouds). These clouds, however, are local structures that appear large and high above the galactic plane because of our perspective, just as buildings look taller the closer you are to them.

The bottom panel is the longitude-velocity map for the same Milky Way region. This map is actually not as much a picture as it is a separator of clouds. This part of the map can be used as a guide to estimate distances based on cloud motion. Although it is difficult to distinguish overlapping clouds in the crowded inner Galaxy, the Carina arm is far enough from the center to stand out by itself. The hook shape of the arm, from about 280° to 310°, is characteristic of a spiral arm; you can actually see the clouds trailing off toward the "backside" of the nucleus. The clouds on the far side of the arm (positive radial velocities) look small and faint because they are far away.

The Work Continues

The data for the inner Galaxy are currently being analyzed by a Harvard-Smithsonian research team led by Patrick Thaddeus. The more complex areas are being observed at full resolution, higher sensitivity, and in different emission lines. By observing carbon monoxide made from different isotopes of carbon and oxygen ($C_{12}O$, $C_{13}O$, etc.) and looking at emission from different rotational levels, we can probe more deeply into the dense clouds and gain information about their physical conditions. In this way, the study of the individual clouds is the study of the first stages of star formation.

Collaboration with astronomers observing at different wavelengths is especially productive. Working with 21-centimeter and gamma-ray data, we are able to calibrate the carbon monoxide emission strength to the amount of molecular hydrogen. Using the same analysis, gamma-ray astronomers can calibrate the galactic cosmic-ray flux. These calibrations can be obtained only



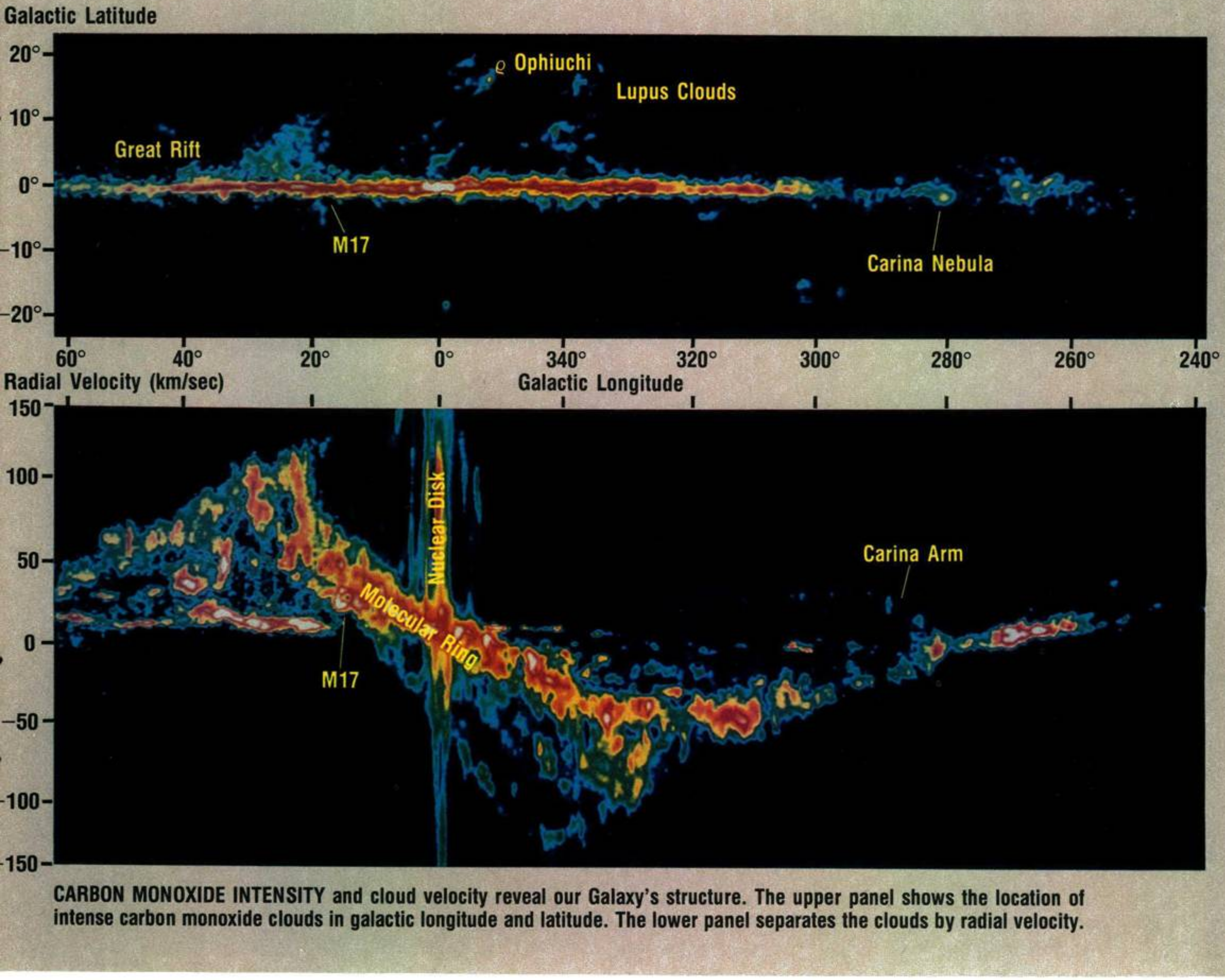
How Astronomers Map Our Galaxy

The bird's-eye view of our Galaxy (left) shows three orbits — the Sun's and two inner orbits — and five clouds, all about the same size, lined up in two directions as seen from the Sun. When astronomers plot radio data as a normal map (intensity, or brightness, on a longitude-latitude grid), the result is like a photograph: the nearest clouds (A and D) appear larger and thus block the more distant clouds. In the longitude-velocity map, however, clouds along the same line of sight can be distinguished by their different velocities, which enables astronomers to plot their distributions in space.

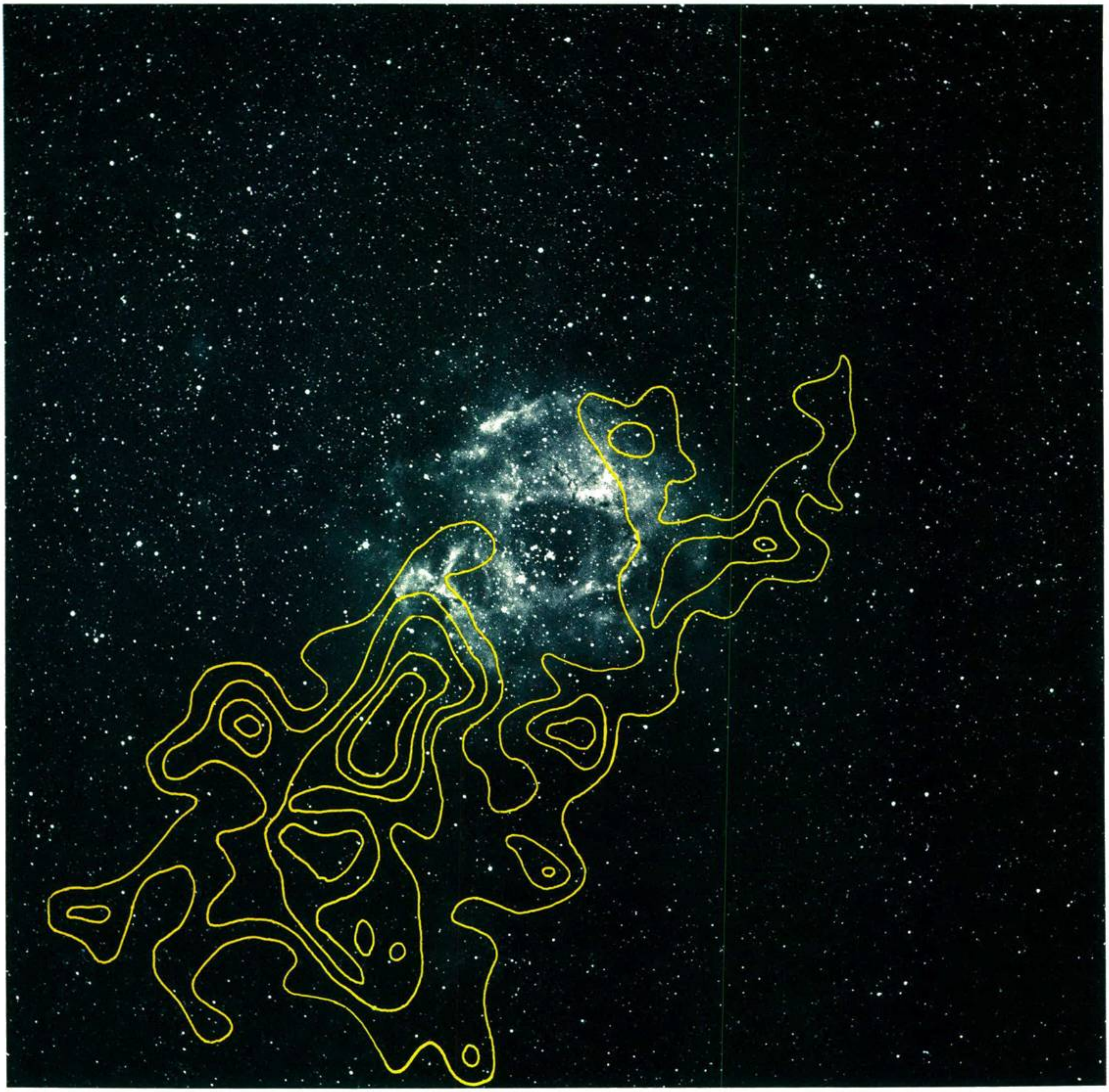
The orbital velocity of a cloud depends on its orbital radius and the mass within its orbit. As a rule, the inner clouds complete their orbits sooner than the outer ones. The highest radial (line-of-sight) velocity measured for clouds in each direction corresponds to the orbit that is tangent to the line of sight. These velocity data yield a rotation curve, which is a plot of how the clouds' orbital velocities vary with distance from the center.

When the rotation curve is known, the observed direction and radial velocity of a cloud uniquely determine the radius of its orbit. Clouds A and C, for example, which have nearly the same radial velocities, are calculated to be on or near the orbit of D.

Although observations uniquely determine the radius of a cloud's orbit, our line of sight crosses that orbit in two places. Cloud A, for example, could be either on the near or far side of the same orbit. When you cannot associate a molecular cloud with an object whose distance is already known, the ambiguity can be resolved in other ways, such as measuring the width of the cloud's spectral lines. Small clouds generally have narrow spectral lines because they have a narrow range of internal motion. Large clouds, however, have a wider range of internal motion and display broader spectral lines. Thus, when a cloud that appears in the sky has narrow lines, it is almost certainly a small cloud on the near side.



CARBON MONOXIDE INTENSITY and cloud velocity reveal our Galaxy's structure. The upper panel shows the location of intense carbon monoxide clouds in galactic longitude and latitude. The lower panel separates the clouds by radial velocity.



PORTRAIT OF A STELLAR HOTBED: The Rosette Nebula and its carbon monoxide cloud (contour lines) are tracers of star birth in our Galaxy.

with a combined analysis: the whole is greater than the parts. A similar collaboration with infrared astronomers is providing powerful tools for attacking the difficult problems of the physics and chemistry of cosmic dust grains.

The giant molecular clouds revealed by carbon monoxide-tuned radio telescopes are the most massive objects in the disk of our Galaxy and make up 10 percent of its mass. As tracers of spiral structure visible across the entire galactic disk, they are giving us our first detailed view of our own Galaxy. When we study planets, we compare them with Earth. When we study stars, we compare them with the Sun. Now, for the first time, we can compare other spiral galaxies to the structure of our Galaxy. In the coming decade, this may enable us to understand star formation on even more fundamental levels and, perhaps, the role it plays in shaping spiral arms. Ultimately, we may come to know how an initially rotating sphere of gas evolved into the flattened disk of stars that today we call the Milky Way. ☐

E. Samuel Palmer is the project engineer of the millimeter-wave telescope facility at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. He teaches astronomy at the Harvard University extension and is on the science panel of Project STAR, a program to develop astronomy curricula for secondary schools.

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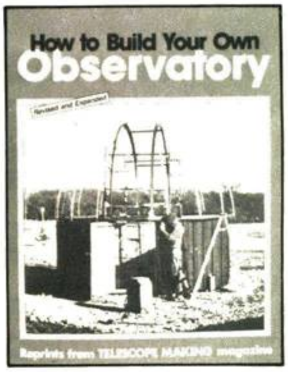

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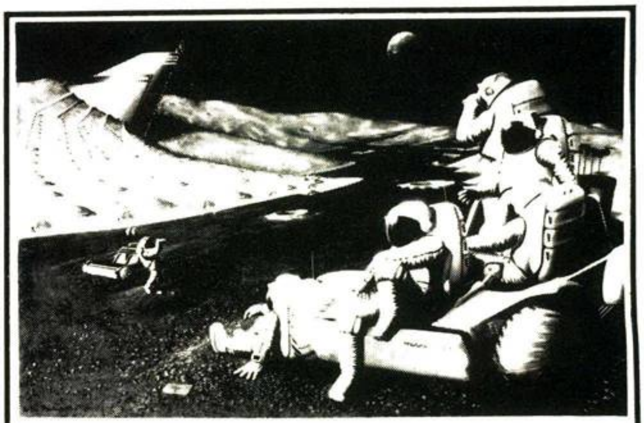

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LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

The "Dumbbell Nebula," M-27 in Vulpecula. The "ears" of the Dumbbell are seen best visually with a Lumicon UHC Filter. Photo by David Healy using a Lumicon Giant EASY-GUIDER and Lumicon hypersensitized 2415 film, 30 min., C-14 at f/6.

20mm NAGLER

Also new 12mm & 16mm NAGLERS

TELE VUE™ EYEPIECES USE THE BEST!!

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Genesis 4" f/5.5 Fluorite Apochromat	$1350
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7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	$89
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55mm 2" Plossl, widest possible field	$219
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7mm Nagler, 1¼" eyepiece, 82° field	$189
9mm Nagler, 82° field, "the best"	$219
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13mm Nagler, 82° field, 1¼" or 2"	$249
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The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

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Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	$39.00	$34.00
52, 55, 58, 62mm	$49.00	$39.00
67, 72, 77mm	$59.00	$49.00
82mm	$69.00	N/A

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

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LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. 1.3-1.8" mirrors have enhanced silver coatings (98-99%R). The extra 8-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**
4.25"	**$149.50**	4.00"	**$149.00**		

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90° star diagonals with 98-99% reflectivity enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$159.00**

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UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 90-97%.

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter or the LUMICON UHC Filter**

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*

Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 85-95%.

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Set of Both premium **DEEP-SKY** and **UHC Filters** (Save 11%), Premium	**$159.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines .... **1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$16.00**
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**Premium filters are selected best of the lot and typically have 5-10% higher transmission. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

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LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

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MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295**

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All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.

Specify Camera and Telescope type.

U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**

Guider for Hasselblad **$350,** Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$195,** Mamiya **$96**

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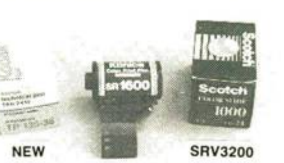
1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**



3. **LUMICON Quartz Drive Corrector** . **$219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.

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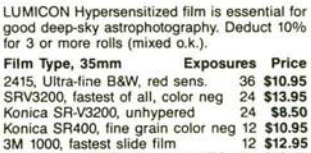

NEW **SRV3200**

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SRV3200, fastest of all, color neg	24	**$13.95**
Konica SR-V3200, unhypered	24	**$8.50**
Konica SR400, fine grain color neg	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
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LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). The coordinates are for Minkowski 1-79, a 13th mag. planetary nebula.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a breakthrough in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

Incredibly Smart!
thus
Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
- Digital decl. readout to 10 arc-min
- NEW! High resolution encoders
- Motor drive ***not required!***
- Polar alignment ***not required!***
- Just sight two stars!

The computer's sophisticated program (over 3000 lines of code) determines **everything** from an initial sighting of just two stars!

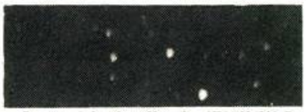
- **No need** to enter latitude, longitude, sidereal time, date, etc.
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080. The computer automatically knows the difference.
- Uses Epoch 2000.0, 1975.0 or 1950.0 coordinates.
- Light weight, only 2 oz. permits mounting near the eyepiece, if desired. Only 2.6"x2.6"x1".
- 9V Battery lasts many nights.

LUMICON SKY VECTOR™ for Meade 2080,2120,C-8,C-11, *(Specify)*	**$498**
For Celestron-14 .. **$575.** For any alt-azimuth (Dobsonian) telescope ..	**$498**
For Coulter Odyssey 8", 10", 13", 17½" *(Specify telescope)*	**$498**
SKY VECTOR KIT. You must supply adapting hardware. For skilled ATM's only	**$449**

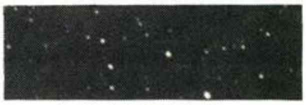
Reference catalogues listing coordinates of 1000's of objects

Burnham's *Celestial Handbook*, Vol. I, II, III (Epoch 1950.0)	**$36.85**
The *Revised New General Catalogue* (all NGC and IC, Epoch 1975.0) .	**$35.00**
Sky Catalogue 2000.0, Vol. II, doubles, variables, deep-sky objects ...	**$29.95**

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7 ..	**$85.00**
2" Adapter for Hasselblad .	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing ...	**$26.00**

1.5x, 1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. It multiplies by 1.5x without the included extension tube. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.5x/1.8x multiplier lens **$235.00**

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FROM $49.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion low profile focuser ..	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" **adapter** w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

MEADE® TELESCOPES

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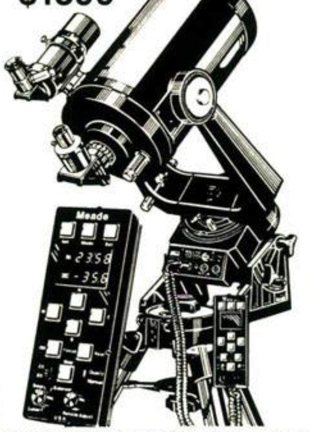
2080/LX6 8" f/6 ..	**$1899**
2120/LX6 10" f/6 .	**$2499**
Digital readout system for 2080/2120/LX6	**$399**
8200 object memory CAT computer	**$999**

NEW 2080/LX6 $1899



Meade Model 2080/LX6: The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

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Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89; 32mm $109**
Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**
Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2080 Original 8" f/10 w/tripod .	**$999**
2080/LX3, 8" f/10 w/MCOG ..	**$1389**
2080/LX5, 8" f/10 w/MCOG ..	**$1599**
2120/LX5, 10" f/10 w/MCOG .	**$1995**
2120/LX3, 10" f/10 w/MCOG .	**$1799**
2045/LX3 4" f/10 w/LX3 drive .	**$795**
#39 declination motor for LX5 .	**$109**
#38 (LX3) or #38A (2045) dec. mtr.	**$99**
Dew shield - essential! 8" **$65;** 10"	**$98**
LUMICON EASY-GUIDER for 2080 ..	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive ..	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

LUMICON ACCESSORIES

48mm COLORED GLASS FILTERS

These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2" eyepieces. Use adapter for 1¼" eyepieces. AR Coated.

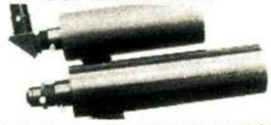
Filter:	**Bandpass**	**Trans**	**2"**	**1¼"**
Ultraviolet	320-420nm	85%	**$35**	—
UV Block	390nm-IR	98%	**$18**	—
Minus Violet	420nm-IR	96%	**$29**	**$18**
Blue Tricolor	340-470nm	80%	**$35**	**$18**
Hi Perf. Blue	300-540nm	95%	**$35**	—
Yellow	480nm-IR	98%	**$18**	**$18**
Green	490-590nm	60%	**$18**	**$18**
Orange	560nm-IR	98%	**$18**	**$18**
Red	600nm-IR	98%	**$18**	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**	—
Cyan	340-580nm	95%	**$59**	**$29**
Polarizer	340nm-IR	40%	**$20**	**$18**
Adapter for 1¼" eyepieces				**$20**
Set of all 11 48mm filters ($318 list)				**$275**

EYEPIECE PROJECTION

These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT.	**$32**
1¼" Basic Camera adapter, 2 part system	**$32**
0.96" Basic Camera adapter, 2 part system	**$32**
1¼" prime Focus adapter, fits 1¼" focuser	**$22**
0.96" prime Focus adapter, fits 0.96" focuser	**$22**
Camera T-ring, specify 35mm camera type	**$12**

LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

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A Cross Section of the Universe

By mapping galaxy clusters in a small region of space, astronomers can see the finescale structure of the universe.

by Jeff Kanipe

From the prow of a small sailboat, the ocean can hardly be considered a smooth, serene environment. Its surface continually undulates with waves, everything from broad swells and frothy whitecaps to tranquil ripples and fleeting whirlpools. Even in relatively calm seas, the sailboat sways steadily, and the deck, as any seasick passenger will tell you, never seems level with the horizon.

From space, however, the sailboat and the waves are vanishingly small and the ocean's surface looks like a deep blue porcelain dish, sleek and unbroken. The waves are still there, of course, but we are so far removed from them that their individuality has merged with the overall wave structure of the sea and the sea appears homogeneous.

Astronomers believe the universe is like this, displaying finer structure at larger scales until at the largest scale it smoothes out into one unblemished whole.

Our Galaxy, for example, is a member of a sparse, loosely connected association of a dozen or so galaxies called the Local Group, contained within a radius about 2.5 million light-years from the Milky Way. At a distance of about 50 million light-years, however, this galaxy group is just a spur of an even larger group of galaxies called the Canes Venatici Cloud. Step back another 100 million light-years and this galaxy cluster itself branches off into other galaxy associations, such as the Leo II Cloud, the Virgo Cluster, and the Crater Clusters — essentially the Local Supercluster.

If we look at even larger scales, we see still more galaxy clusters woven into a complex fabric of clusters that seem to extend to the edge of the visible universe. Besides the obvious clustering effect, one of the most striking features of this fabric is that it isn't perfect. In fact, there are huge holes in it, vast regions of space that are largely devoid of galaxies, millions upon millions of light-years of emptiness.

Even at these immense scales, astronomers can still see large-scale structure: traceries of light where the galaxies are; voids where the galaxies are not. The question arises, then, of how large the largest structure in the universe must be.

Galaxies Trace the Structure

An early approach to discerning large-scale structure simply involved mapping galaxy distribution across the sky. The Swiss astronomer Fritz Zwicky, who had studied galaxy clusters since the early 1930s, conducted an ambitious survey between 1961 and 1968 of over 7,000 galaxies in the northern sky. Even though it was a two-dimensional representation, Zwicky's map still showed certain regions that were quite rich in galaxies, and others that seemed galaxy poor.

The most recent approach has been to map the three-dimensional distributions of galaxies across large swaths of sky. A cross section such as this traces out the largest structures we can see, the galaxy clusters, and reveals something of the true framework of the universe.

For the past five years, Margaret Geller and John Huchra of the Smithsonian Astrophysical Observatory, along with French astronomer Valerie de Lapparent and various colleagues, have mapped sky positions and distances for 2,500 galaxies in the northern sky. Their map covers a colossal wedge of intergalactic space: An 18°-wide by 120°-long strip of sky extending 450 million light-years deep. Yet, said Geller, this survey represents only about 1/100,000 of the total volume of the visible universe.

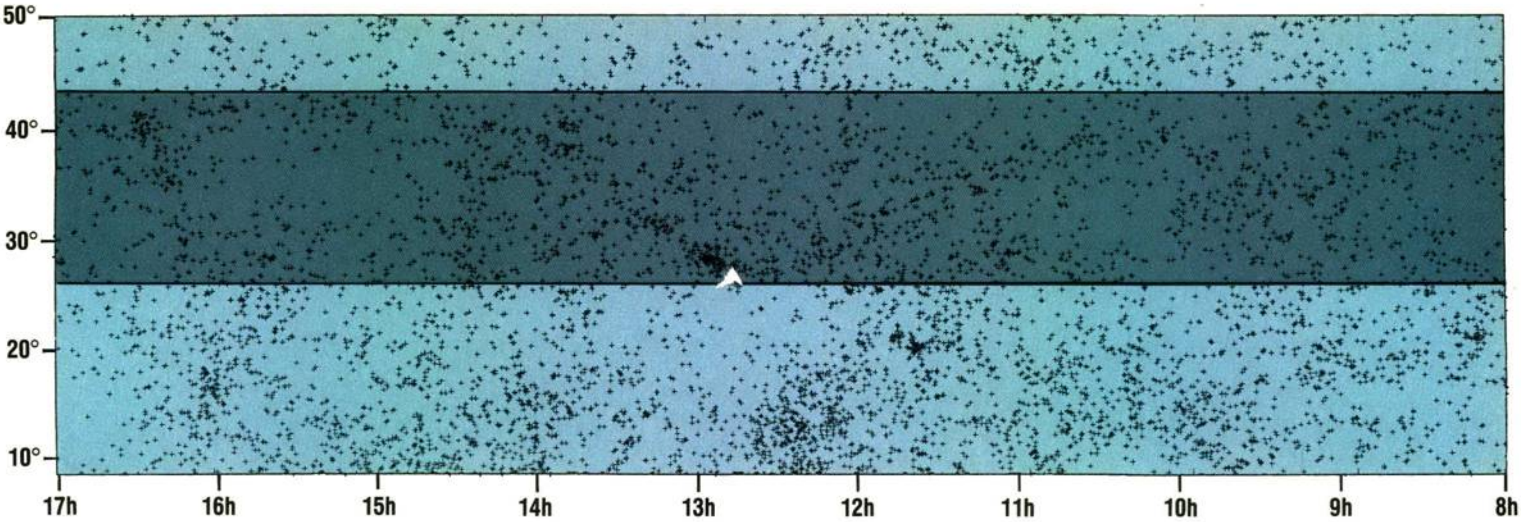
Their plot appears on the opposite page. Our Galaxy lies at the apex of the wedge, and each plotted galaxy is denoted by a yellow or red cross. Right ascension arches across the "top" of the wedge, from 8 hours on the right to 17 hours on the left. The wedge is divided into four declination slices, from +26.5° to +44.5°, indicated by the four white lines. A distance scale based on the galaxies' recessional velocities (given in kilometers per second per megaparsec) extends radially from the apex.

Dark Matter Makes Itself Known

The patterns of large-scale structure that emerge in Geller, Huchra, and de Lapparent's survey have profound implications for cosmology. One of the more intriguing implications has to do with the dark-matter problem. Perhaps, like ocean waves, the large-scale structure we see in the map represents only that which lies on the surface.

The dark-matter problem arises when astronomers compare a galaxy's recessional velocity with its internal motion in the galaxy cluster. Recession velocity is obtained from a galaxy's redshift (i.e., how far a galaxy's spectral lines are displaced toward the red end of the spectrum compared with terrestrial, or at-rest, spectral lines). The greater the redshift, the faster the galaxy is receding and, in accordance with the Big Bang theory, the farther away it is.

This expansion, however, is not smooth because of the perturbing motions caused by the gravitational attraction of the other members in the galaxy cluster. For example, the red "torso" figure in the center of the map is the Coma Cluster, the nearest populous cluster of galaxies. Measurements of the amount of light emitted by the stars in the galaxies in the Coma Cluster yield an estimate of the total mass of the cluster. According to Newton's laws of physics, however, the total amount of "visible" mass falls short of the amount needed to gravitationally bind the cluster by a factor of 10. That means fully 90 percent of the mass in the universe is unaccounted for.


50°
40°
30°
20°
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17h
16h
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13h
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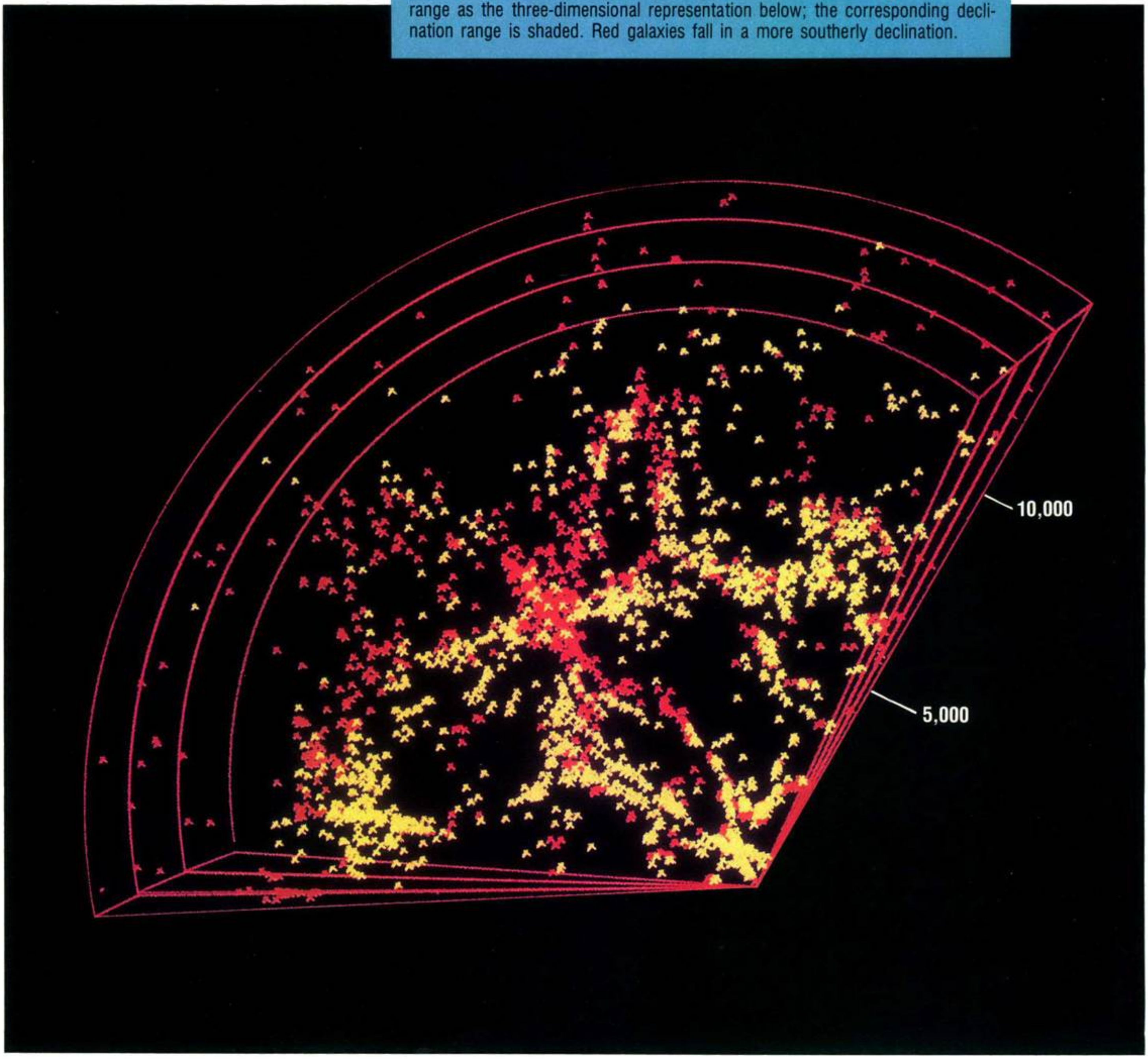
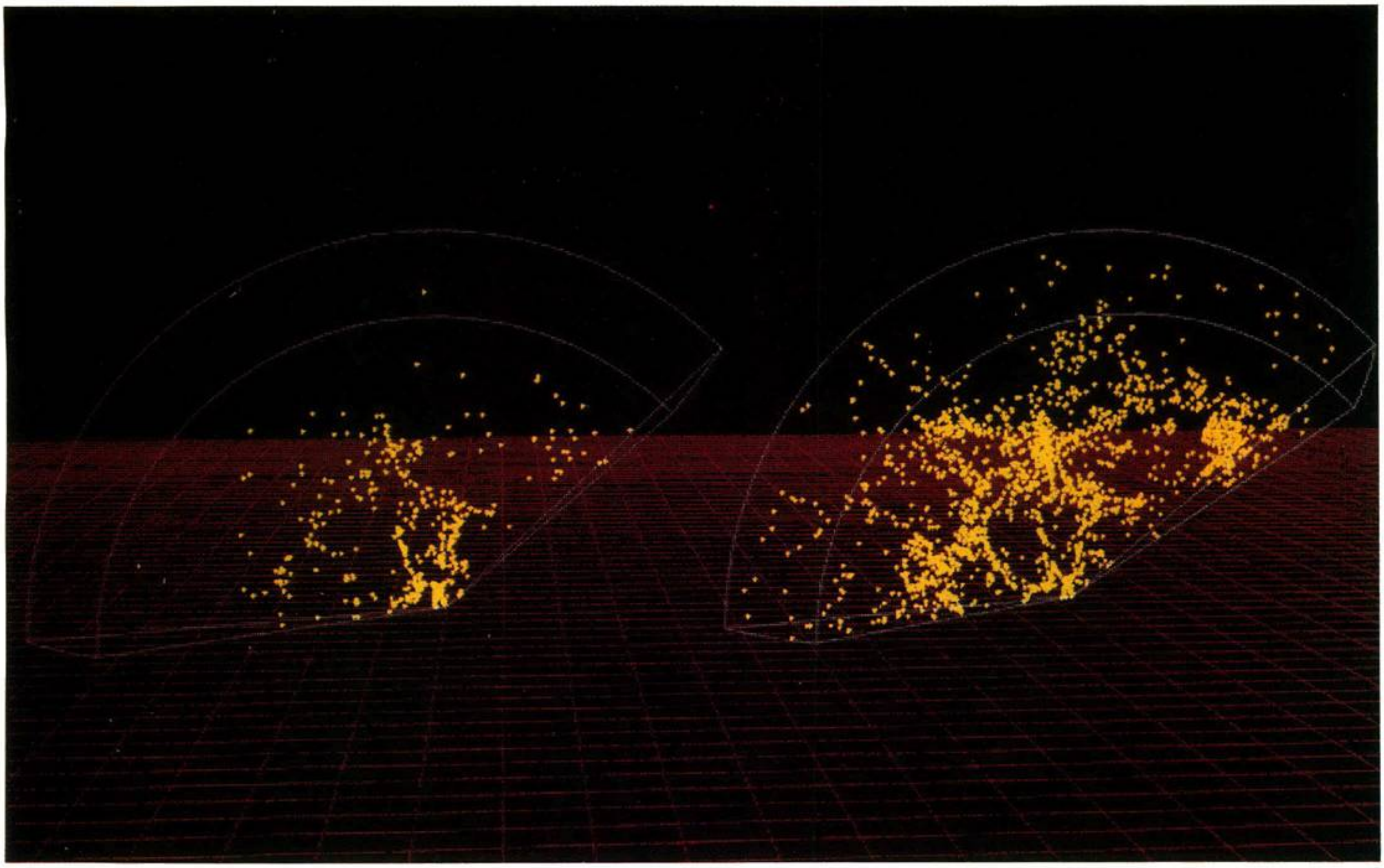
11h
10h
9h
8h

OVER 7,000 GALAXIES were plotted on this Cartesian coordinate map from the 1960s by astronomer Fritz Zwicky. The map covers the same right-ascension range as the three-dimensional representation below; the corresponding declination range is shaded. Red galaxies fall in a more southerly declination.





MORE STRUCTURE is apparent at fainter magnitudes. The magnitude limit of the left slice is 14.5; the right slice is 15.5. The voids don't go away.

The Big Bang theory dictates that the majority of the dark matter cannot consist of ordinary particles — protons and neutrons — because that much additional matter in the early universe would have produced a higher abundance of helium than is observed today. Advances in particle physics may eventually identify the major constituents of dark matter and the role it plays in the dynamics of large-scale structure.

Where the Voids Are

A feature as compelling as where the galaxies are is where the galaxies are not. These voids shot through the sheets of galaxies actually occupy more volume than the clusters; the largest in Geller and Huchra's slice is at least 160 million light-years across. (Voids have also turned up in other galaxy surveys. One of the largest voids, called the Bootes void, has a length of 350 million light-years.)

According to Geller, the largest voids observed so far are the largest that can be detected within the limits of the survey. "Every survey big enough to contain a void does so," said Geller. Granted, the diameters of the largest known voids represent only about 1 percent of the radius of the visible universe, but as astronomers survey larger volumes of space larger voids are not necessarily precluded.

Geller says that if larger voids are found, it will force astronomers to abandon one of the fundamental precepts in cosmology: the universe, like the ocean from space, is homogeneous at some sufficiently large scale. This Copernican viewpoint, which goes by the high-sounding name of the cosmological principle, asserts that there are no preferred locations in the universe, that there is no "center" or "edge," and that all places are alike.

Supporting the cosmological principle is the smoothness and ubiquity of the 2.7-Kelvin microwave background radiation, which is thought to be the cooled, residual radiation of the Big Bang. Sensitive searches for variations in this temperature have, instead, confirmed its uniformity. On scales of 1.5 arcminutes, temperature fluctuations amount to a few parts in 100,000. Had the seeds of galaxy clusters and voids been sown in the early universe — had enormous explosions blown holes in the primordial gas, for example — they should be detected today as irregularities in the microwave background. But the microwave background's extraordinary smoothness testifies to the fact that matter in the early universe must have been distributed very uniformly.

The striking patterns apparent in these galaxy cluster surveys have given us a tantalizing glimpse of how the universe is structured. They clearly show that on the scale of galaxies and galaxy clusters the universe is inhomogeneous, even though it is thought to be homogeneous at the largest scale. They also show that these structures are *big* and allude to even larger structures; many of the voids and galaxy filaments extend right "off the map."

These surveys also pose some difficult questions. When did the galaxies form, and how did they form in a smooth universe? If we hold to the cosmological principle, how much of the universe must be surveyed before one region begins to look like all the others? And if not all the mass is apparent, then what must be observed in order to understand the universe?

Larger and deeper surveys are needed (in fact, two such surveys are currently underway — one in the Northern Hemisphere and one in the Southern Hemisphere). Also necessary are precise measurements of the microwave background temperature (also ongoing) to search for significant variations. It all fits together somehow, but like an exploded jigsaw puzzle the picture won't make sense until we find more of the missing pieces and place them in the proper cosmic perspective. □

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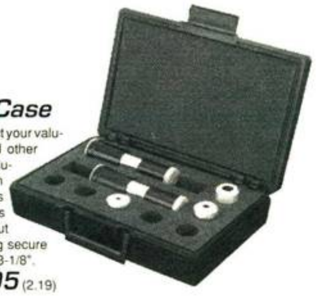

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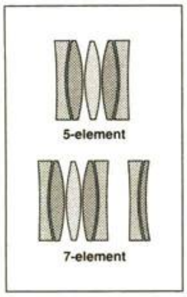

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Probing Saturn and Titan by Starlight

Observers turned a rare alignment of Saturn with a bright star into new insights about the planet's rings and the atmosphere of its largest moon.

Inside the Rings of Saturn

By Robert Irion

When Saturn and its ring system passed in front of the star 28 Sagittarii on July 3, 1989, backyard astronomers hunched over their eyepieces to observe the fascinating sight of the star flickering on and off as its light filtered through Saturn's semitransparent rings. Many amateur astronomers tracked the changes in the star's brightness by speaking into a tape recorder that was simultaneously recording time signals broadcast by shortwave radio. The resulting tape allowed the observers to construct a profile that showed how the rings' transparency varied during the three-and-a-half-hour event.

Lick Observatory astronomer Richard Stover was no different, except he was using a 40-inch reflector atop Mount Hamilton in California. His CCD detector took roughly 11,000 individual images of Saturn and 28 Sagittarii at a rate of one per second, eventually collecting 110 megabytes of data. Shown in rapid succession, the individual frames form a movie of the event. Although the job of reducing the raw observations to scientifically useful data has only begun, Stover is confident of good results.

Astronomers were greatly interested in this occultation because it provided a rare opportunity to probe the small-scale structure of the Saturnian ring system. In August 1981, the photopolarimeter instrument aboard *Voyager 2* used 2nd-magnitude Delta Scorpii to "x-ray" the rings in just the same manner.

A major goal for astronomers studying this occultation is to determine whether the ringlets observed eight years ago by *Voyager 2* have changed in location, size, or thickness. Lick Observatory's results will be combined with results from more than a dozen other groups to produce a map that will reveal the rings in more detail than *Voyager 2* could do with its single trace across the rings.

Another advantage of the 28 Sagittarii occultation observations is the larger aperture of the telescopes and more sensitive equipment used to observe the event. Although 28 Sagittarii is dimmer than Delta Scorpii, the detector aboard *Voyager 2* is much less sensitive to changes in light than today's ground-based instruments. Thus, the 28 Sagittarii occultation may actually let astronomers see through parts of the rings that *Voyager* couldn't penetrate.

Stover said that months of painstaking work lie ahead of him as he analyzes each frame individually to separate the star's light from that of the rings. "It's an incredibly tricky task," said Stover. "When done, we'll know the positions of the rings very well, but the brightnesses of the individual ringlets may have errors of 10 or 20 percent."

Curiously, Stover isn't a planetary astronomer. His main research interest lies in cataclysmic variable stars, extremely close binaries that vary rapidly in brightness as matter moves from one star in the system to the other. Yet the equipment he uses to study variable stars was just right to monitor closely the rapid changes in 28 Sagittarii's brightness.

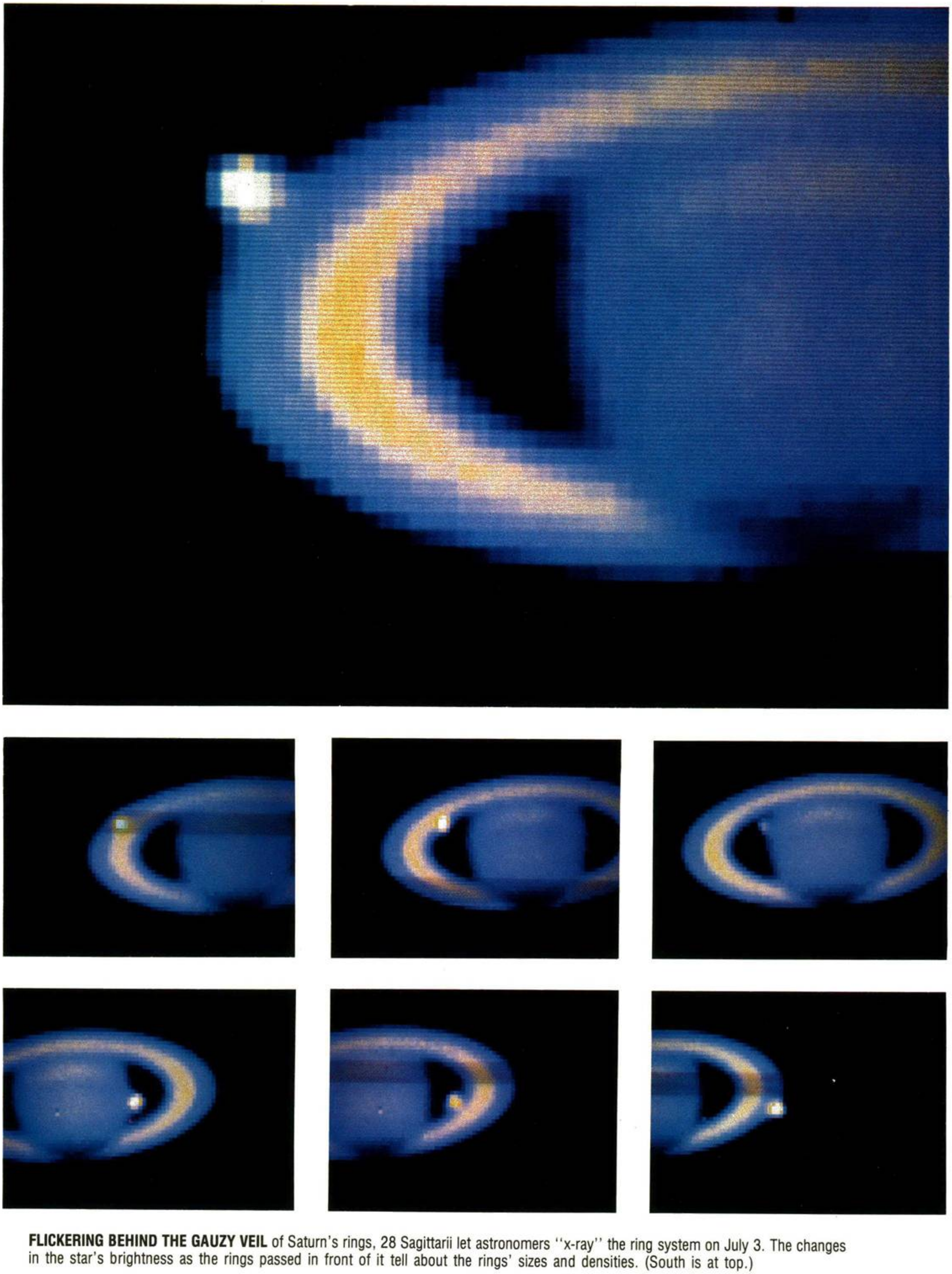
"I had only about two minutes to set up for the occultation, because Saturn was so low in the sky at the observatory," he said. "The telescope can point down to only 24° above the horizon; when the occultation began, Saturn was barely higher than that." Nonetheless, Stover managed to catch the entire event, from the immersion of the star into the A ring until it emerged from the A ring on the other side of Saturn.

He halted the observations when the star was hidden by Saturn, then turned on the equipment fifteen minutes before the moment when the star would lie directly behind the planet. Stover hoped to spot a central flash, predicted to occur when the star's light, refracting through Saturn's atmosphere, might create a brief blip of light precisely at mid-occultation. As it happened, Stover detected no trace of a central flash, probably because the star passed too far from the center of Saturn as seen from Lick Observatory.

Jeffrey Cuzzi, a specialist in planetary rings at NASA's Ames Research Center in nearby Mountain View, California, said that when all the occultation data have been analyzed, this event may let astronomers resolve new ring details in regions both with and without a lot of ring material. "*Voyager* was 'blind' in many places because the rings were too dense," he said. "Also, we may be able to resolve new structures in areas that are thin on material. Even ring arcs may be present — Neptune has taught us that ring material doesn't have to encircle a planet."

Cuzzi noted that from Earth the star's image swept a path through the rings about a dozen miles across, considerably larger than the 1,000-foot resolution obtained by *Voyager*. "However, we now have several tracks across the rings from different observatories, and it's exciting to think we can now build up a more complete picture."

Robert Irion is a science writer and public information officer at the University of California, Santa Cruz.



FLICKERING BEHIND THE GAUZY VEIL of Saturn's rings, 28 Sagittarii let astronomers "x-ray" the ring system on July 3. The changes in the star's brightness as the rings passed in front of it tell about the rings' sizes and densities. (South is at top.)

European Amateurs Study Titan

by Andrew Hollis and Jacqueline Mitton

The last time the tiny disk of a planet's moon passed directly in front of a bright star was when Jupiter's moon Io occulted Beta Scorpii in 1971. By an amazing stroke of good fortune, on July 3 of this year, Titan, the largest moon of Saturn, occulted the 5.4-magnitude star 28 Sagittarii. The event was part of the general occultation of the star by Saturn and its ring system, which was widely observed in the Western Hemisphere.

The occultation of a bright star by Saturn is rare. When this particular event was predicted several years ago, European observers were resigned to missing out on the action because calculations showed that the occultation would take place over Europe well after Saturn had set. Then, early in 1989, Larry Wasserman of Lowell Observatory made a more detailed prediction, which showed that Titan would also occult the star.

Wasserman's calculations suggested that the center of the shadow track would pass over the USSR, Turkey, and North Africa, and a short occultation lasting one or two minutes could be seen from northern Europe. As it turned out, the prediction was very slightly in error. The end result, however, was better for Europeans than the original prediction — the central line of the occultation passed through northern Europe (see diagram on page 54), where large numbers of backyard astronomers were ready and waiting anyway.

What could observers expect to see? When an airless body such as the Moon occults a star, the starlight snaps off in a fraction of a second. The brightness may oscillate up and down briefly as a result of diffraction — a slight bending of the light rays around the obstacle — but the event appears instantaneous to the eye.

Voyager showed us, however, that Titan has a dense atmosphere. Viewers could therefore expect the star to fade slowly over many seconds, as its light passed through ever deeper and thicker layers of atmosphere, until the light was wholly absorbed or scattered.

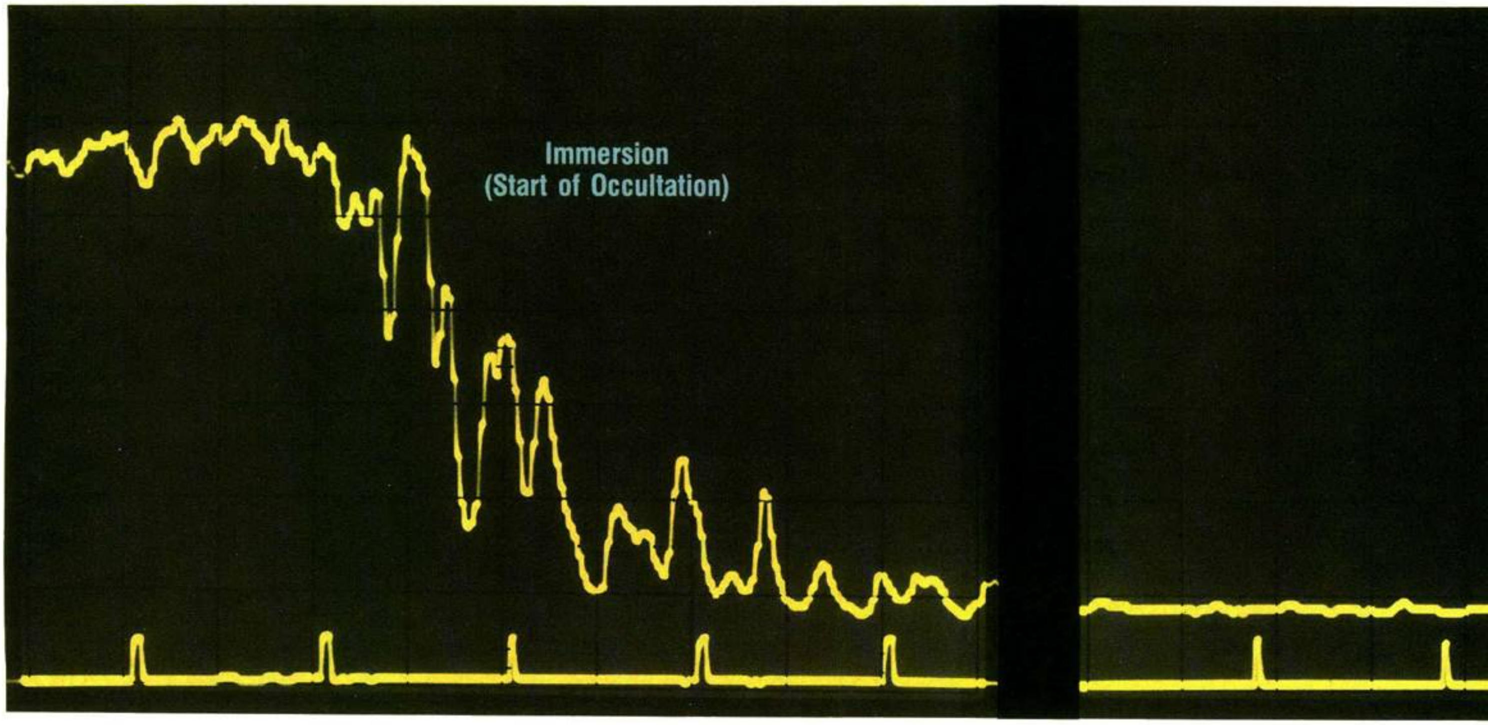
But the starlight would not fade smoothly. Haze layers in Titan's upper atmosphere and variations in temperature with altitude were expected to refract the passing starlight by different amounts. This would create areas on Earth where the starlight is focused and reinforced and other areas where the light is attenuated. As the occultation proceeded, an individual observer would stand alternately in one type of zone and then the other, and thus would see a flickering star.

The most dramatic example of light reinforcement is a sudden surge in brightness at mid-occultation called the central flash. For an observer on or close to the center line, light passing through the lower levels of the atmosphere briefly focuses an image of the star and creates an abrupt flash. In effect, Titan becomes a lens. The predictions suggested that a central flash might be seen somewhere during the event, but because European observers did not realize they were observing near the center line, they didn't anticipate seeing a central flash.

The low declination of Saturn, −22°, meant that its maximum altitude above the horizon was only 10° in the United Kingdom. This low altitude presented considerable difficulties for observers. All observers found the atmospheric seeing poor, and some discovered trees and bushes intercepting their line of sight. Most viewers did what they could about the difficulties — offending bushes were pruned or the telescopes were moved.

The low elevation conferred one benefit. The path of the occultation was spread widely across Earth so more people could see it. For instance, ten miles' distance perpendicular to the line of sight corresponded to sixty miles projected on Earth's surface.

By early August, 125 occultation observers had reported to the British Astronomical Association. Most observed visually, timing the disappearance and reappearance of the star. Some used portable tape recorders to make running commentaries. Two teams used photoelectric photometers and seven used video equipment.



One or two attempted direct multiple-exposure photography.

The greatest surprise was the large number of observations of the central flash, which turned out to be an increase in brightness of about one magnitude that lasted for five seconds. All of the photoelectric traces and videos from U.K. observers recorded the flash and about half the visual observers reported it as well. It was seen as far north as Dundee, Scotland, and Sweden and as far south as the Pyrenees. This means the central flash was visible in a band more than thirty miles wide perpendicular to the line of sight to Titan.

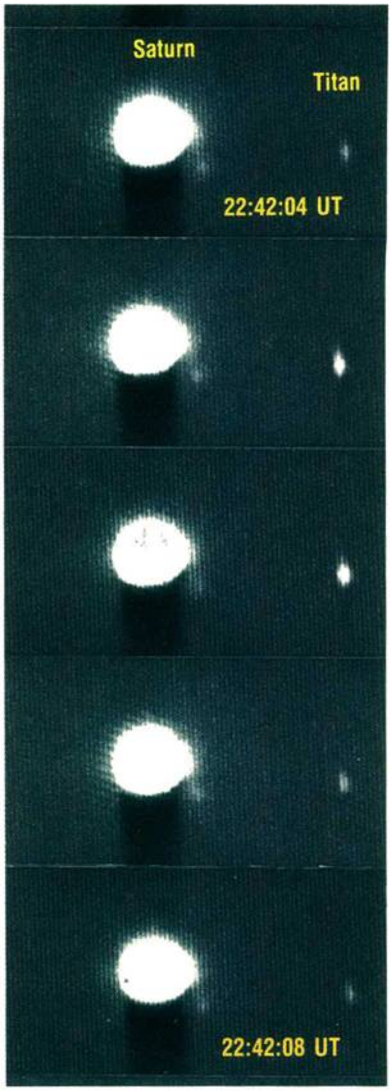
When the occultation began and ended, many observers were confused by the star's flickering brightness. Typical was the commentary recorded at the telescope by Nick James of Chelmsford, Essex: "It appears to be fading — definitely fading. Yes, it's gone. It's gone. It's still there! You can just see it. But it's gone — it's gone now. No, it's still there!"

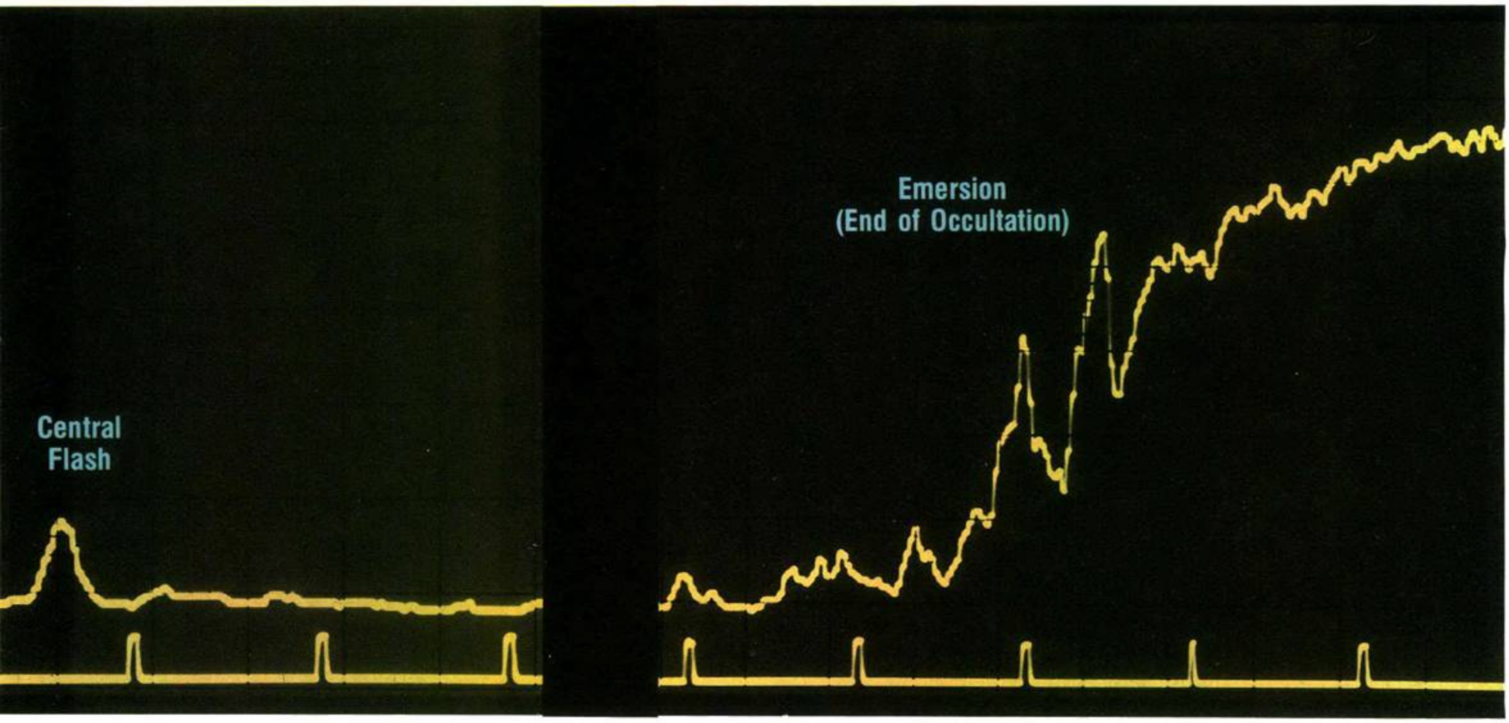
The photoelectric trace made by Richard Miles and Andy Hollis showed twenty-six spikes in brightness at immersion (beginning) and twenty-four at emersion (end). They correspond well with spikes in a trace produced at the Hatfield Polytechnic Observatory near London and with a digitized analysis of a video made by Terry Platt in Berkshire. There are records of the occultation from at least ten sites in the United Kingdom operated by amateurs. These represent ten soundings of Titan's atmosphere and ten different tracks across the central flash.

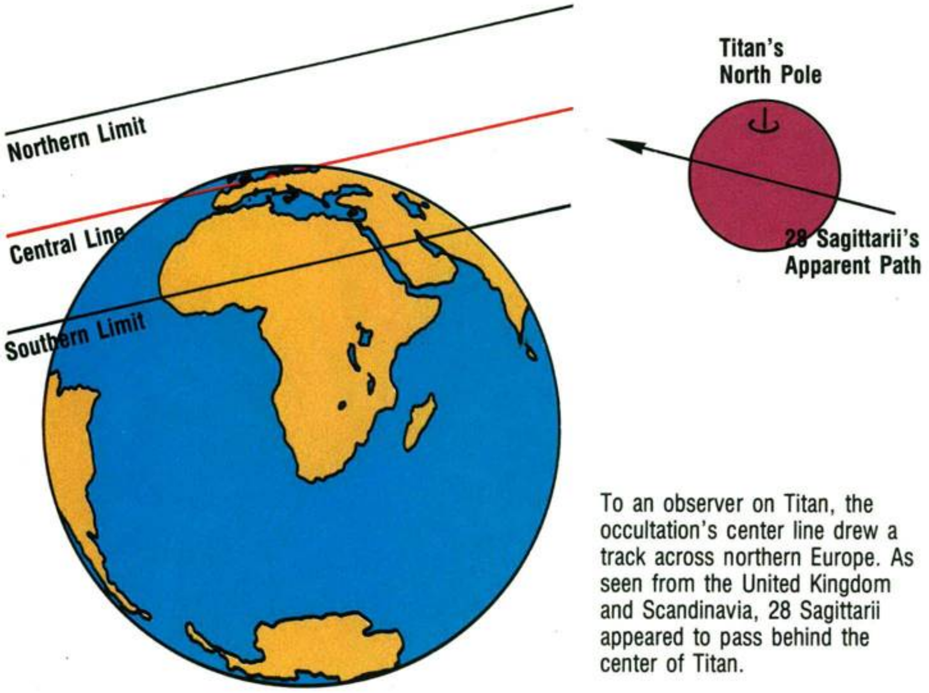
Visual observers experienced a lot of difficulty trying to measure the precise moment when the edge of the disk of Titan crossed the minute disk of the star. The difficulty came about because 8th-magnitude Titan and 5th-magnitude 28 Sagittarii appeared to fuse about twenty minutes before the occultation was due, and the combined light of both objects was only about 0.1 magnitude brighter than the star alone. Before the occultation started, scintillation (made worse by the low altitude) caused the star to vary in brightness, but this "noise" dramatically dwindled once Titan's atmosphere started crossing in front of the star. The explanation for this phenomenon is that refraction in Titan's atmosphere broadened the stellar point source into an extended source that didn't twinkle.

The brightness spikes were variable. Some were sharp, lasting less than a second, and of high amplitude. Others were broader, lasting five seconds or so. Differences between the spikes at the start and end of the occultation suggest that the temperature profile in Titan's atmosphere varies over distances of a few miles — an interesting result. Once the occultation was total,

THE CENTRAL FLASH took many Titan observers by surprise. The photometric trace below covers the whole occultation; the video frames at right, taken at 1-second intervals, bracket the flash.







To an observer on Titan, the occultation's center line drew a track across northern Europe. As seen from the United Kingdom and Scandinavia, 28 Sagittarii appeared to pass behind the center of Titan.

the combined light dropped by a factor of ten.

Because it was so unexpected, the central flash took many observers by surprise. Believing the occultation would last only one or two minutes, some viewers actually thought they were witnessing emersion. David Graham recorded: "Now then, is it starting to brighten up? I think we must scotch that — it looks just as faint as it did before." Andrew Hollis and Richard Miles together recorded the following dialogue:

Miles: It's coming — there was a little peak there.

Hollis: Could be the central flash.

Miles: I got a peak — that could be the central flash — there's definitely a distinct peak — isn't that amazing?

Hollis: I told you it was possible.

Miles: I thought it was on its way out and then it suddenly went back again.

The occultation observations are important because they can provide information about the structure of Titan's atmosphere, particularly the way in which temperature varies with height. Planetary scientists have established that Titan's atmosphere consists mainly of molecular nitrogen. Titan is the only body in the solar system, other than Earth, for which this is true. (The surface pressure is also 1.6 times that at the surface of Earth.)

The surface of Titan and any clouds in the lower atmosphere are concealed by a global layer of orange haze at a height of 140 miles. There is no oxygen, but a small proportion of methane plays an important role in the atmospheric chemistry. Ultraviolet light from the Sun breaks the methane molecules down into hydrogen atoms and methyl radicals, which are very reactive chemically. They produce heavier hydrocarbons, hydrogen cyanide, and other organic compounds, including polyacetylenes and cyanide polymers.

This organic material gradually rains or snows onto the surface, where it accumulates in a deep layer or perhaps dissolves in oceans of liquid methane. The surface temperature is a globally uniform 95 kelvins, just above the melting point of methane. In principle, Titanian weather, with clouds and methane rain, is possible or even likely.

Planetary scientists have determined the main trends in how the temperature of the Titanian atmosphere changes with altitude from the way the radio signals from the *Voyager 1* spacecraft were weakened as they passed through the atmosphere. Up to a height of 25 miles, the temperature decreases steadily to a minimum of 74 K. It then rises rapidly over the next 15 miles or so and eventually reaches a constant maximum of about 180 K at a height of 150 miles.

Analyzing the data from this occultation consists of using the brightness spikes to work out both the refractivity and the temperatures at different altitudes in the upper atmosphere. Conditions at the lower atmospheric levels control the length and intensity of the central flash; interestingly, the photoelectric traces appear to show structure in the central flash, but this is not yet confirmed.

A by-product of the observations is an upper limit on the size of 28 Sagittarii, which is a K-type giant star. The size can be deduced from the sharpest spikes in the occultation light curve, which represent focused images of the star. The sharpest spike of all seems to have lasted 0.2 second, which indicates an angular diameter no greater than 0.00055 arcsecond. The star's estimated distance is 487 light-years and the corresponding upper limit on its diameter is 13 million kilometers — almost ten times that of the Sun.

All of the observers who have commented agree that this astronomical event was one of the most interesting and exciting they had witnessed. "One of the most breathtaking sights I have had," said Martin Cartwright of Emsworth. "Fabulous. A gorgeous observation," was David Frydman's reaction.

On occasions like these, any amateur astronomer can savor the rewards of his or her efforts. Not the least of these is knowing that the observations contribute in a unique way to the advance of astronomical knowledge. These observations contain significant information about the structure of Titan's atmosphere and could well prove of value in the planning of a space mission to explore Titan early next century.

Many intriguing questions remain to be answered about Titan. The presence of organic molecules regarded as important precursors to life on Earth may mean that Titan has something to teach us about the early evolution of Earth's atmosphere. Detailed information about the temperature profile in the atmosphere will be one step towards uncovering the mysteries of Titan.

Whatever the answers are, the prize for ingenuity and free-thinking should go to an anonymous young boy. His thirteen-year-old friend wrote, "I have recorded an unexplained observation — 28 Sagittarii flashed for a fraction of a second. I don't understand this. A friend of mine at school attributed it to a hole cut all the way through Titan, but I am, to say the least, slightly skeptical!" ☐

Andrew Hollis is director of the Asteroids and Remote Planets Section of the British Astronomical Association. Jacqueline Mitton is editor of the Journal of the British Astronomical Association *and a writer specializing in astronomy.*

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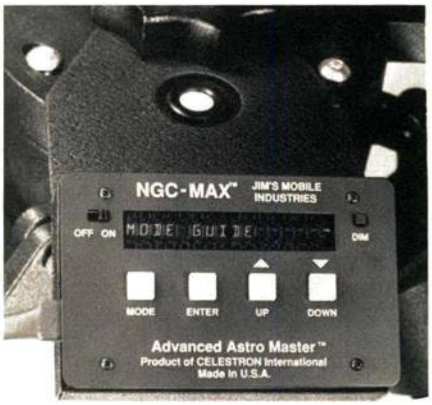

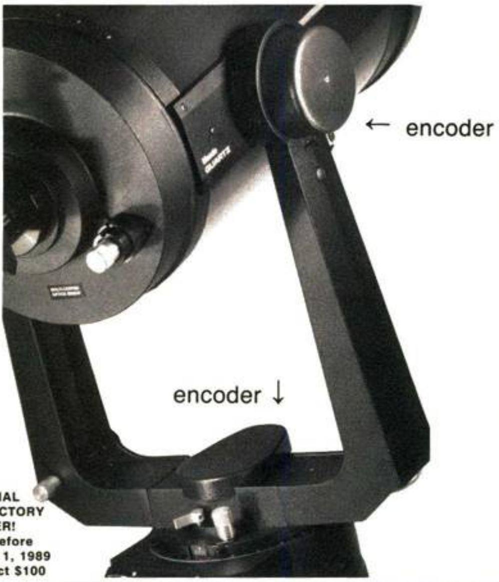

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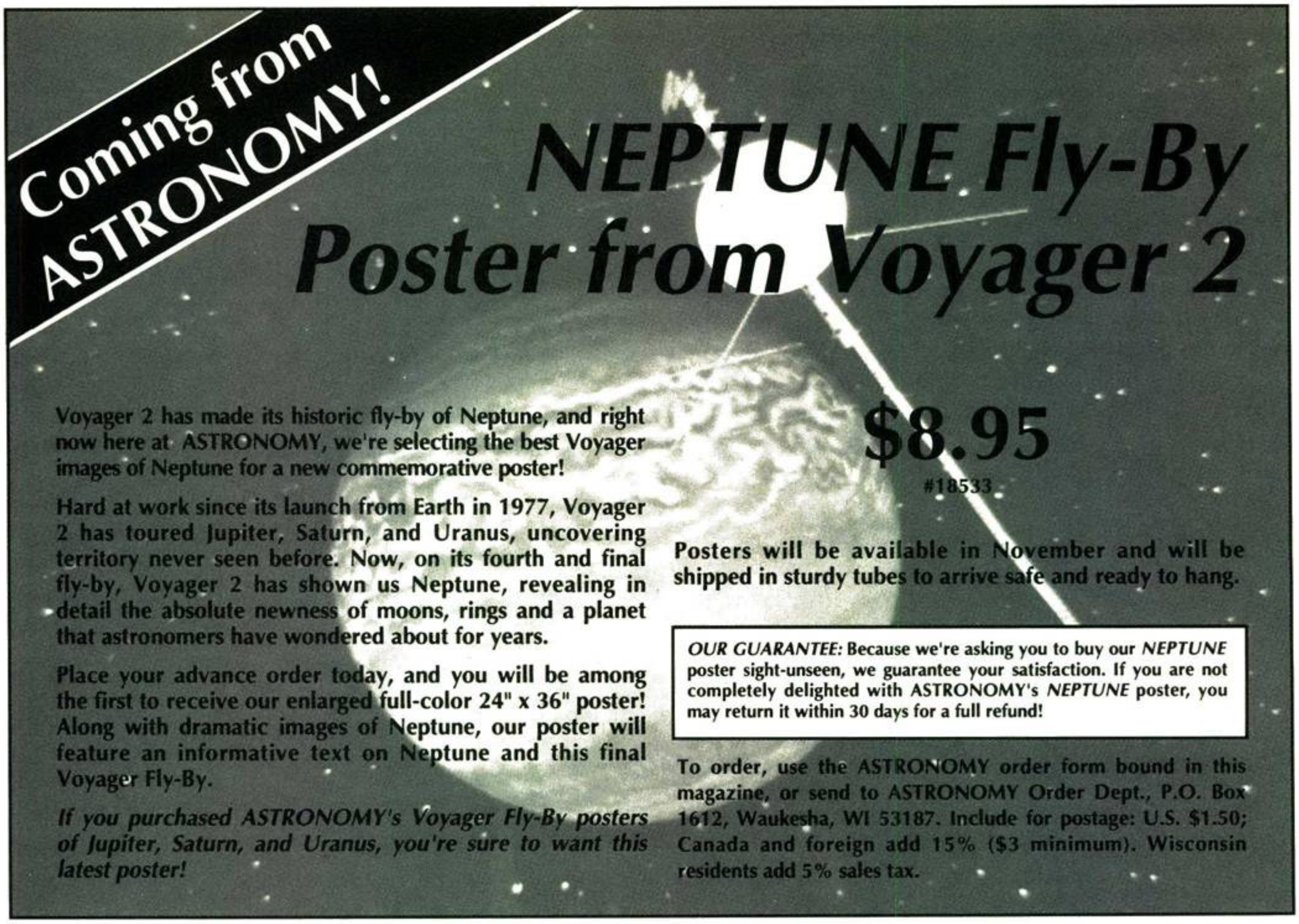

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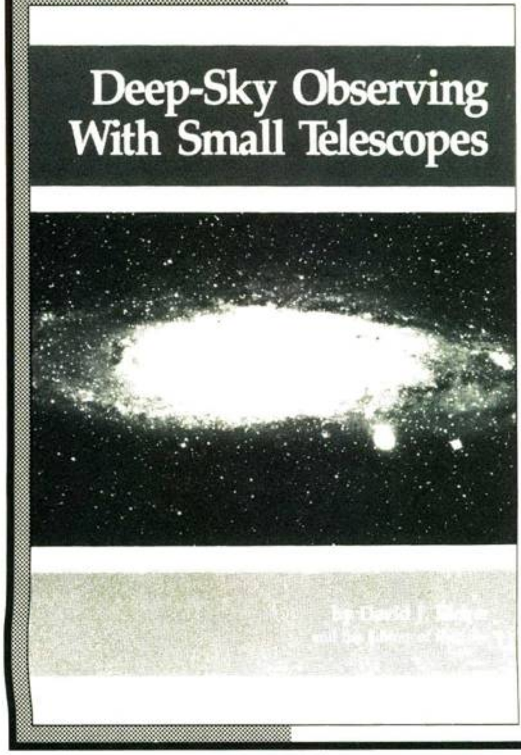

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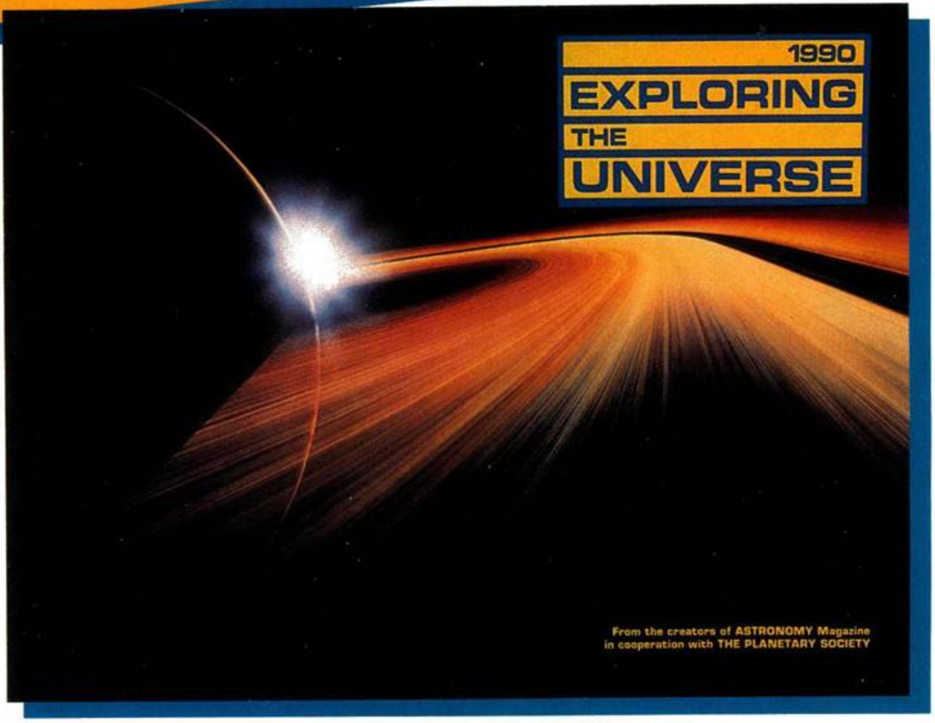
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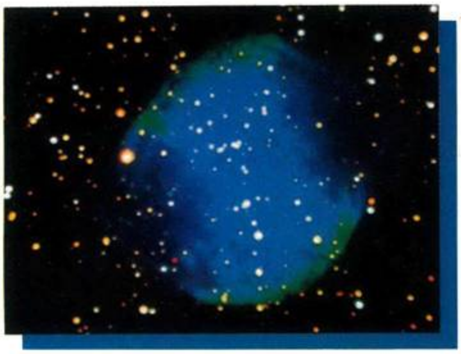

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The all-sky map shows how the sky looks at:
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8:00 p.m. on November 15
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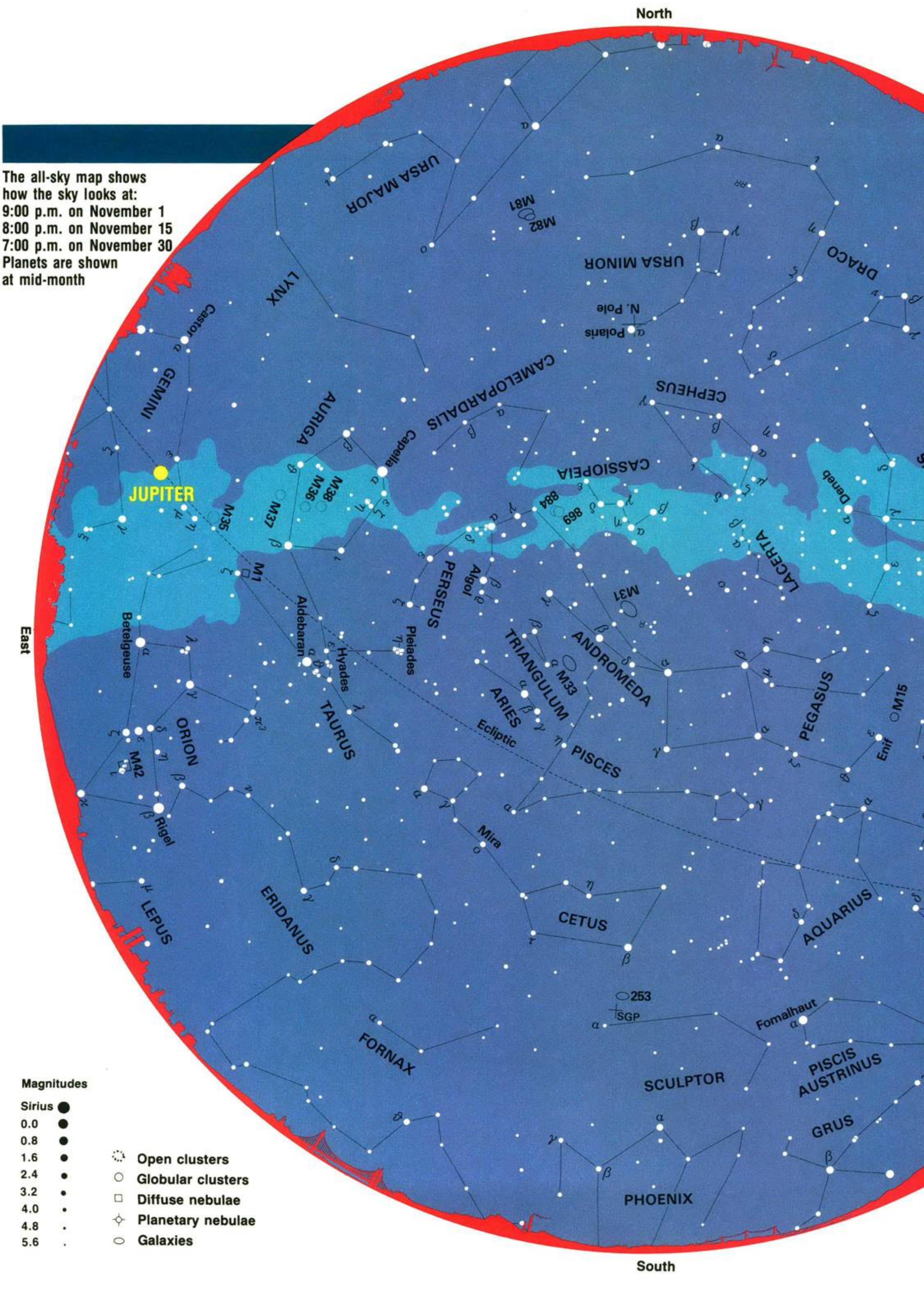
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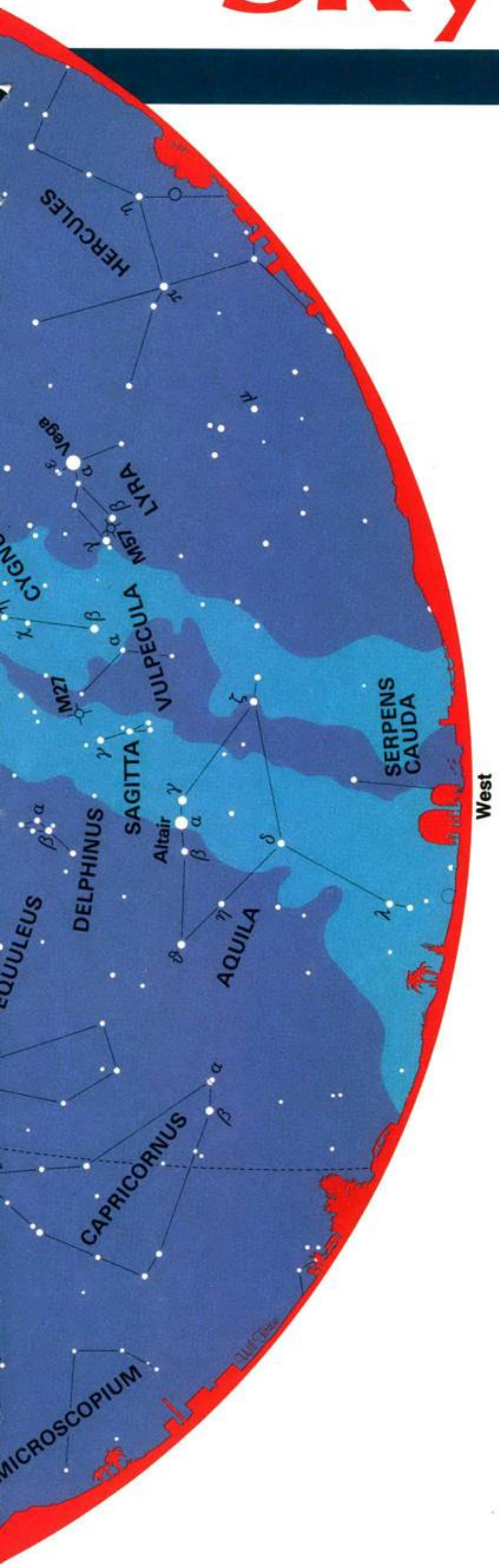


VENUS, THE MOON, AND SATURN

November is an exciting month for Venus watchers. On November 2 the brightest planet lies just 1° north of the slim crescent Moon shortly after sunset. As the month progresses, Venus climbs noticeably higher in the southwest evening sky, where it passes 4° south of Saturn on November 15.

UNUSUAL CHANGES ON JUPITER

Rising earlier with each passing day, Jupiter is a brilliant light in the east in the late evening. But the most interesting view is left to telescopic observers, who can follow the unexpected fading of the giant planet's South Equatorial Belt.

SATURN AND NEPTUNE AGAIN

For the third and final time this year, you can find Neptune quite easily using Saturn as a guide. The outermost planet lies just 0.5° north of Saturn on the evening of November 12.

THE MOON HIDES THE BEEHIVE

A waning gibbous Moon passes in front of the famous Beehive Cluster in Cancer on November 18. Observers in western North America and Hawaii can see the event in the early morning hours.

Dates and Times

1 The Moon passes 0.2° south of Antares, 6 a.m. EST

2 The Moon passes 0.7° south of Venus, 5 p.m. EST

3 The Moon passes 4° south of Saturn, 4 p.m. EST

6 First Quarter Moon is at 9:11 a.m. EST

7 Pluto is in conjunction with the Sun
Venus passes 3° south of Uranus, 9 p.m. EST

8 Venus is at greatest eastern elongation (47°)

10 Mercury is in superior conjunction

12 The Moon is at perigee (222,120 miles from Earth), 8:20 a.m. EST
Saturn passes 0.5° south of Neptune, 4 p.m. EST

13 Full Moon is at 12:51 a.m. EST

15 Venus passes 4° south of Neptune, 10 a.m. EST
Venus passes 4° south of Saturn, 2 p.m. EST

16 The Moon passes 3° north of Jupiter, 9 a.m. EST

17 Leonid meteor shower peaks

18 The Beehive Cluster is occulted by the Moon, 9 a.m. EST

19 Last Quarter Moon is at 11:44 p.m. EST

24 The Moon is at apogee (252,361 miles from Earth), 10:47 p.m. EST

28 New Moon is at 4:41 a.m. EST
Thyra is at opposition

Eye on the Sky by Deborah Byrd

A BUSY MONTH FOR VENUS

This month it is impossible to overlook Venus, which shines in the southwest after sunset as the glittering evening "star." Venus, the brightest planet visible from Earth, reaches greatest elongation on November 8. On that date the planet is at its greatest separation from the Sun — 47° — and shines brilliantly at magnitude −4.4.

Venus' most spectacular event in November occurs on the evening of November 2. A very slender crescent Moon lies about 1° from the bright planet that evening. In North America, observers along the East Coast have the best view of the conjunction because the 16-percent-lit Moon lies closest to Venus just after sunset. In western North America, the Moon and Venus appear slightly farther apart, though they still form a striking pair in the early evening sky. (The Moon occults Venus in parts of the Southern Hemisphere, but the event is visible after dark only from the southern tip of Argentina.)

A less spectacular, though still very interesting, event occurs in mid-November when Venus climbs past Saturn. Both planets are moving through Sagittarius, intruding on the otherwise easy-to-discern asterism known as the Teapot. Saturn lies a little over 10° above Venus at the beginning of November. At magnitude 0.5, Saturn is three times brighter than the brightest star in Sagittarius, yet it pales in comparison to the nearly one hundred times more luminous Venus.

As the month progresses, you can see the two planets pull closer together. They are closest on November 15, when Venus passes 4° south of Saturn, though they remain within 5° of each other for several days around the 15th. By November 20 the two edge into a side-by-side position in the southwestern twilight sky.

THE CRESCENT MOON and Venus are an eye-catching pair on the evening of November 2. A similar view greeted photographer Gary Nickerson on January 21, 1988.

JUPITER BECOMES PROMINENT IN THE EVENING

Jupiter appears progressively earlier in the evening sky this month as it moves toward its late December opposition. It rises in the east-northeast around 9 p.m. at the beginning of November and around 7 p.m. by month's end. At magnitude −2.6, the giant planet easily outshines all the other objects in the sky except the Sun, Moon, and Venus.

Jupiter is now in a very prominent place among the stars. Like a king surrounded by his courtiers, the planet is ringed by the brightest stars visible on winter evenings. These stars form a circular pattern that is sometimes called the Winter Circle, and Jupiter is now the bull's eye of this eminent circle.

This positioning provides an excellent opportunity to notice the major difference between stars and planets as they appear to the naked eye: stars twinkle and planets shine steadily. Just compare any of the bright stars in Jupiter's vicinity with the planet. The stars twinkle like crazy, while Jupiter shines rock-steady.

NOVEMBER'S PLANETS

Venus is well placed for viewing after sunset this month. The bright planet, which sets nearly three hours after the Sun, is at greatest elongation on November 8 and is fairly high in the southwest as darkness falls. Venus, however, is not as high in the sky this month as it can be.

The planet's separation from the Sun is only half of the story. The other half concerns the ecliptic, or "road of the Sun," which is also followed closely by the Moon and planets. If the ecliptic pointed straight up from the western horizon at sunset — as it does in early spring — then Venus would be high in the sky. In the evening at this time of year, however, the ecliptic tilts toward the south; thus Venus remains relatively low in the sky. In fact, two days before greatest elongation Venus lies farther south than it has in eight years. It will not be as far south again until 1997.

The best time to view Venus during this apparition is in December. The ecliptic swings to a more perpendicular position with respect to the evening horizon in December; therefore Venus edges higher in the twilight sky. The planet is also slightly brighter in December.

Saturn is as easy to overlook as Venus is hard to miss. Saturn is a soft, yellowish light above Venus in the southwest when the month begins and beside Venus around mid-month.

Saturn will not linger in our evening sky much longer. Earth passed between it and the Sun in early July, and we are now far ahead in our smaller, faster orbit, watching Saturn fall back into the Sun's glare. The ringed planet will disappear from view next month but will reappear in the predawn sky in late January.

The giant planet Jupiter is well up in the east by midnight this month. At magnitude −2.6, the largest planet is nearly two magnitudes — a factor of more than five — fainter than Venus. Yet Jupiter, unlike the inner planet Venus, can appear far from the Sun in our sky, so it doesn't have to compete with the twilight glow.

Jupiter now lies in Gemini, where it dominates the sky from mid-evening until dawn. This is a good month to compare Jupiter's location with that of Venus and Saturn. Jupiter is almost directly opposite the other two planets in the sky, which means it rises in the east-northeast at the time Venus and Saturn set in the west-southwest. In addition, Jupiter lies in a direction nearly opposite the center of our Galaxy. Saturn and Venus meanwhile lie in the approximate direction of the Galaxy's center.

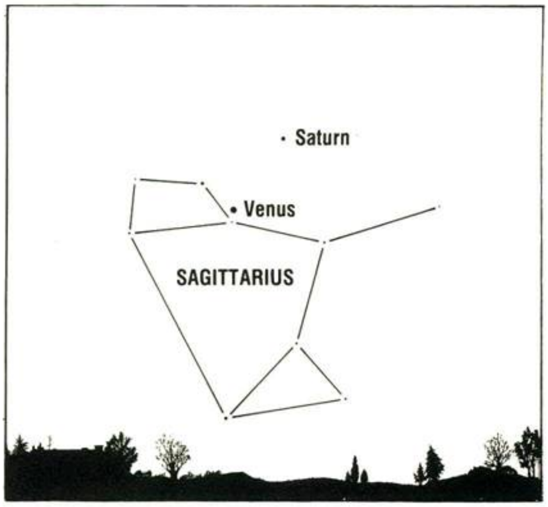
After having been lost in the Sun's glare since August, Mars returns to the predawn sky this month. By the end of November, it can be seen low in the east-southeast shortly before sunrise. The Red Planet is in Libra by month's end, where it shines at magnitude 1.6.

This is the beginning of a new apparition for Mars. Although it won't get quite as bright as it did in late 1988, Mars will be much brighter in the second half of 1990 than it was at anytime during 1989.

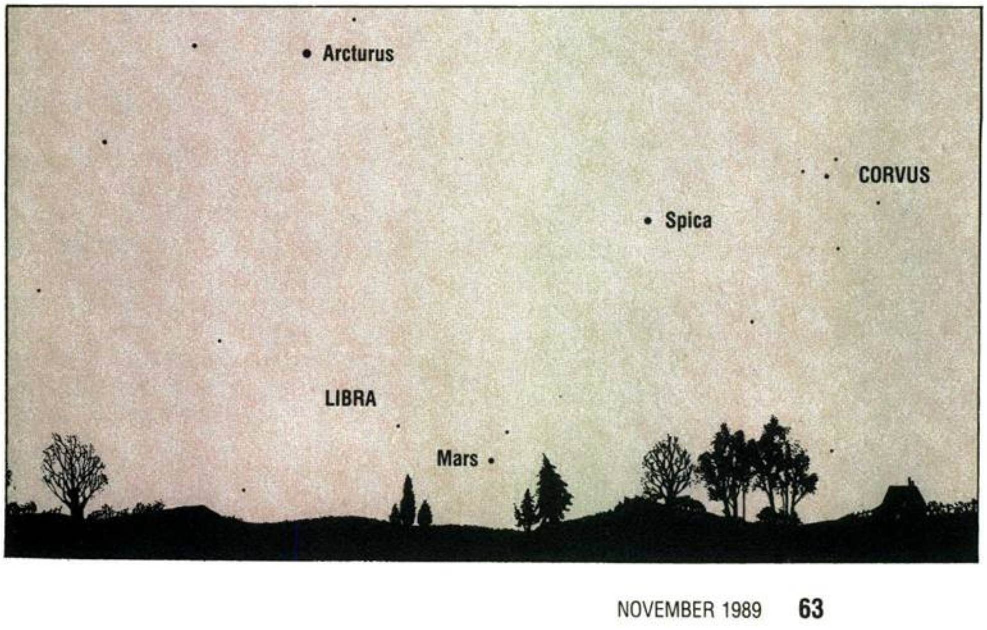
Mercury is not visible this month. It is in superior conjunction, behind the Sun as seen from Earth, on November 10. Mercury will again be visible in the evening sky in the latter part of December.

NOVEMBER'S STARRY SKY

Aries is an inconspicuous constellation, located in what was once an important place in the sky. Although it is small and easy to overlook, Aries has been called



SATURN SINKS as Venus climbs in November's evening sky. The two planets lie just 4° from each other as darkness falls on the evening of November 15.



MARS RETURNS in late November to the morning sky, where it appears low in the east-southeast an hour before sunrise.

the "Prince of the Zodiac."

To find Aries in the November night sky, look for a more conspicuous constellation, graceful Andromeda. Aries lies about 20° southeast of Andromeda's brightest stars. Aries itself has only two fairly bright stars, 2nd-magnitude Hamal (Alpha [α] Arietis) and 3rd-magnitude Sheratan (Beta [β] Arietis). Fortunately, these two stars lie only 4° apart, which increases your chances of noticing them.

What's more, Aries, a zodiacal constellation, sometimes plays host to the Sun, Moon, and planets. There are no planets in Aries now, and the Sun won't arrive there until next April. The nearly Full Moon, however, can be seen near Hamal and Sheratan on the night of November 11.

In the lore of the heavens, Aries represents a Ram. In Greek mythology, it is the fabled Ram with the Golden Fleece. According to an ancient Greek legend, the ram was sent by the god Hermes to rescue two children — Phrixus and his sister Helle — from their cruel stepmother. Helle unfortunately fell from the ram's back as they flew across the strait dividing Europe from Asia, but Phrixus was carried to safety. He landed in the land of Colchis, on the shores of the Black Sea, where he sacrificed the ram and gave its precious fleece to the country's king, Aetes.

Later the crew of the great ship Argo, including many of the greatest Greek heroes, set out in search of the Golden Fleece. Ultimately, after many adventures, they captured the fleece from King Aetes.

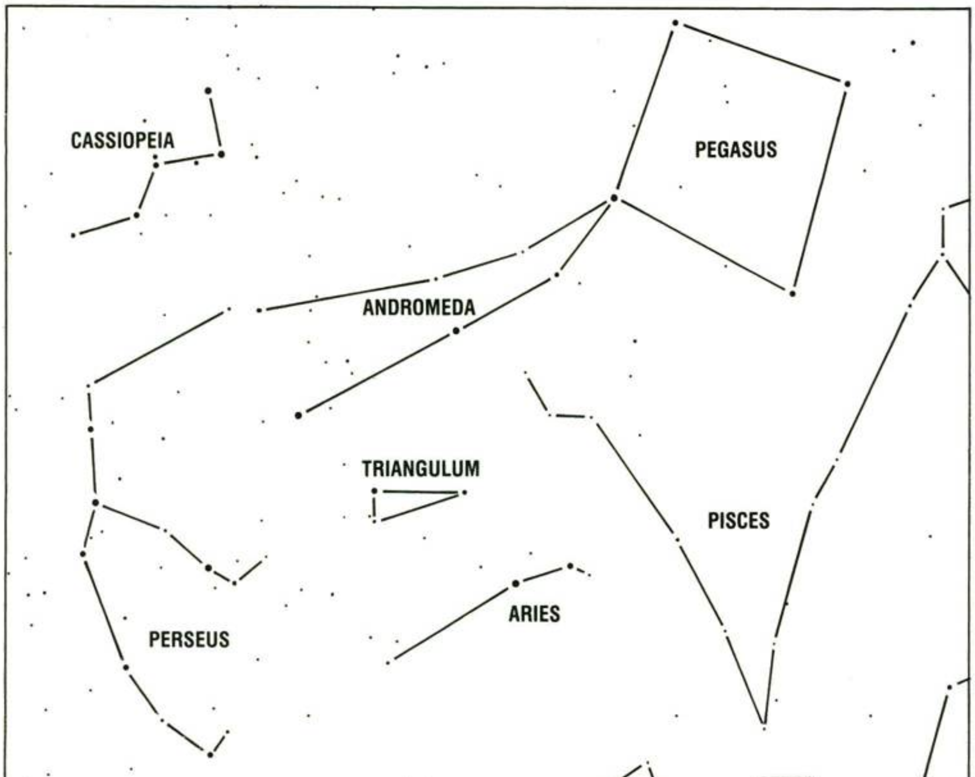
Although Aries is a small and inconspicuous constellation, many cultures have considered it to be significant. The Egyptians, for example, began their new year when the Sun entered Aries.

Its significance stems from the fact that, between 1800 B.C. and A.D. 1, the Sun lay in Aries at the time of the vernal equinox. Ancient astronomers called the Sun's position at this equinox "the first point of Aries." It still bears this name, by the way, even though the Sun on the day of the equinox has now moved into the constellation Pisces. The position of the equinox has shifted during part of the 26,000-year cycle known as precession, which causes the direction of Earth's rotational axis to trace out a circle among the stars.

By definition, the first point of Aries has zero right ascension and zero declination. Because precession shifts the point's position over time, the coordinates of all the stars and other objects in the sky also shift. This keeps celestial cartographers busy, because they must update their atlases to keep pace with the changing positions. This accounts for the fresh crop of star atlases, with coordinates that center on the year 2000.

The first point of Aries will continue to shift, by the way. In another few hundred years it will move into the constellation Aquarius, and the real Age of Aquarius will begin.

ARIES RIDES HIGH in the east on November evenings near the constellations Andromeda and Perseus.



Through the Eyepiece by Rick Shaffer

SATURN AND NEPTUNE: THE FINAL ACT

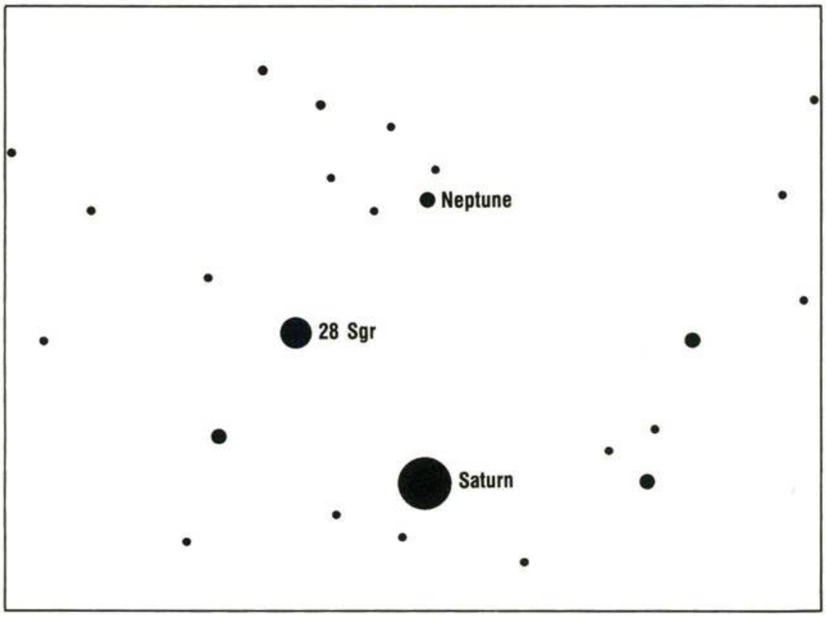
This has been an especially exciting year for telescopic observers of Saturn. Saturn had two close conjunctions with Neptune in March and June, then there was the spectacular occultation of 28 Sagittarii in July. November brings the last major event in Saturn's 1989 apparition: the ringed planet's third conjunction with Neptune. This is the last time these two planets will be visible in the same field of view for several decades, so you won't want to miss it.

Saturn passes only 0.5° south of Neptune on the evening of November 12. Observers in eastern North America have the best view. As the sky darkens around 6 p.m. EST, the two gas giants are only two hours removed from their closest approach. West Coast observers have to wait an additional three hours (until 6 p.m. PST) for darkness to fall, and by then the planets have separated a bit. Still, because they move so slowly, the two planets remain in the same field of view under medium magnification. In fact, they linger within 1° of each other for a few weeks before and after their conjunction, so you have several opportunities to observe them together at low power.

Use a low-power eyepiece for your first look at Saturn and Neptune. Although you won't see any details on the planets at low power, you will see the planets' contrasting colors most vividly. Because Saturn has a higher surface brightness than Neptune, its cream-to-tan color appears more vivid than Neptune's blue-gray color.

Once you have viewed the colors of the two planets, switch to the highest-power eyepiece that still gives you a clear, crisp view. Saturn's 16"-diameter disk should show one or two dusky bands under most conditions. If you use a 6-inch or larger telescope and have good seeing, you may see several more.

It is Saturn's ring system, however, that makes viewing this planet exciting. The 35"-diameter rings are now opened wide to our view, which makes seeing details in them relatively easy. Look particularly for the Cassini division — the narrow, dark gap that separates the outer A ring from the brighter middle B ring. You might also glimpse the thinner and more elusive Encke division near the outer edge of the A ring, but you will need excellent seeing conditions to do so.

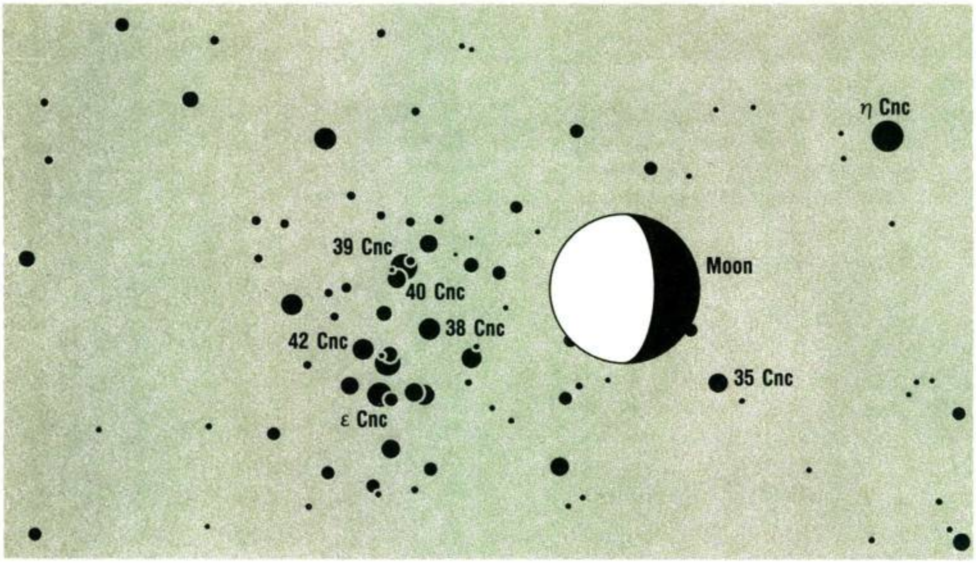


FIND ELUSIVE NEPTUNE by looking 0.5° north of much brighter Saturn early on the evening of November 12.

Eighth-magnitude Neptune, unfortunately, reveals little on its small 2.2"-diameter disk. The wealth of atmospheric detail recently photographed by the *Voyager 2* spacecraft is all but invisible from Earth. Even professional astronomers using very large aperture telescopes can see only vague, low-contrast hints of this detail.

DRAMATIC CHANGES IN JUPITER'S ATMOSPHERE

When Jupiter emerged from the morning twilight last July, telescopic observers were amazed to see only one dark equatorial belt. According to Jose Olivarez and Phillip Budine, Jupiter recorders for the Association of Lunar and Planetary Observers, Jupiter had displayed two prominent equatorial belts for more than a decade. During May, however, the South Equatorial Belt began to fade and by July it appeared as no more than a pale ghost of its former self.



THE MOON OCCULTS M44, the Beehive Cluster in Cancer, as seen from western North America on the morning of November 18. Observers in Honolulu can see the waning gibbous Moon poised on M44's edge at 1 a.m. local time.

With Jupiter now just a month away from opposition, you have plenty of opportunities to observe the giant planet. Jupiter rises in the early evening and is high in the sky — where the seeing is usually better — for much of the night. Observe with the highest power that affords you a sharp image of the bright planet's 45″-diameter disk. Although no one knows for sure what Jupiter's atmosphere will do next, it's quite possible that the Great Red Spot will darken and the South Equatorial Belt will return to prominence in late 1989 or 1990.

Jupiter is a fascinating object to observe any time, but with major atmospheric changes underway it is even more exciting this year. Try to observe Jupiter every clear night you can, and pay special attention for signs of further changes on the planet as a whole and in the South Equatorial Belt in particular. If you notice anything unusual or interesting, send a brief report to Olivarez and Budine, ALPO Jupiter Recorders, 1469 Valleyview Court, Wichita, Kansas 67212.

THE MOON AND A SWARM OF BEES

Observers along the West Coast of North America and in Hawaii can see the Moon pass in front of the open star cluster M44, known as Praesepe or the Beehive, on the morning of November 18. The geometry of this occultation is such that if you're located east of Denver, dawn breaks as the Moon approaches the Beehive. Farther west, the occultation begins earlier and you can see more of it before morning twilight interferes. From western North America, start observing no later than about 4 a.m. PST, and from Hawaii be ready by 1 a.m. local time.

Because the Moon is close to Earth, our perspective on the occultation varies across the globe. From Hawaii the Moon appears to pass through the center of Praesepe, while from farther north along the West Coast of North America, the Moon passes through the southern regions of the cluster.

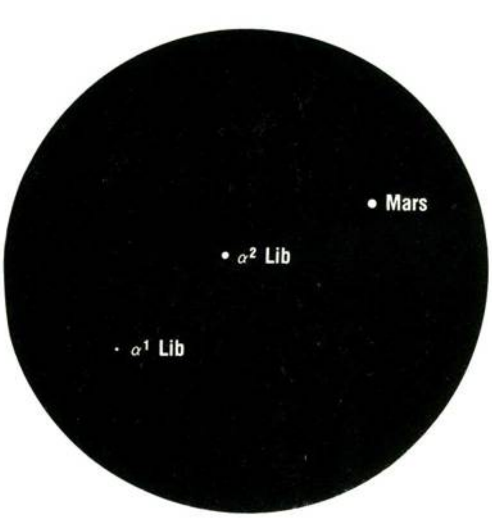
Seeing some of the Beehive's individual stars occulted may be difficult, however. The Moon is 66-percent lit at the time of the occultation, so it is bright enough to overwhelm many of the fainter cluster members. Also, the Moon's phase is waning, so the stars disappear behind the lit part of the Moon. Nevertheless, you should have little problem seeing the cluster members pop out from behind the Moon's unilluminated limb. You'll have to keep alert at the eyepiece, however, because you won't have any warning that a star is about to reappear.

The fact that stars reappear suddenly at the end of an occultation indicates something fundamental about the Moon: it has no atmosphere. If the Moon had an atmosphere, a star would appear dim as it emerged because its light would be attenuated by the thickest part of the atmosphere near the Moon's surface. The star would then brighten gradually as it "rose" out of the atmosphere, finally returning to its normal brightness only after it had risen completely above the atmosphere.

TELESCOPIC PLANETS

I hope you saw Mercury's excellent morning apparition last month, because the innermost planet is essentially lost from view behind the Sun in November. You might spot Mercury briefly, very low in the west-southwest, thirty minutes after sunset on the last day of the month.

MARS PASSES JUST SOUTH of Alpha¹ and Alpha² Librae on the morning of November 26. The three objects appear in the same field of view through an 8-inch f/10 telescope at 300x at 5:30 a.m. EST.



During December the speediest planet moves higher in the evening sky where it has a fairly nice apparition late in the month.

Venus begins the most interesting portion of its current evening apparition this month. The brightest planet reaches its greatest elongation east of the Sun — 47° — on November 8. The day before that Venus' disk appears exactly half illuminated, which marks the halfway point in the visual appearance of Venus during this evening apparition. But Venus is quickly catching up to Earth in its faster orbit around the Sun. Whereas Venus has taken seven months to go from superior conjunction, when it appeared fully lit, to a half-lit appearance, it takes only a bit over two more months for Venus to reach inferior conjunction, when it appears totally unlit.

Because of its orbit, changes in Venus' telescopic appearance are rapid and easily noticeable this month. On November 1 Venus shows a 53-percent-lit disk measuring 23″ across, and by November 30 the planet's phase has shrunk to 36-percent lit and its disk has grown more than 40 percent to 33″ in diameter. Over the same period Venus brightens slightly, from magnitude −4.4 to −4.6. One final piece of good news for observers: Venus finally climbs out of the horizon murk in November. After hovering about 15° above the southwest horizon at forty-five minutes after sunset from July through October, Venus gains 5° in altitude during the course of November.

Three months after it disappeared into the evening twilight, Mars reappears in the morning sky around mid-November. Although you'll be able to see the 4″-diameter disk of Mars, you'll be lucky to pick up any details on the Martian surface.

This does not mean, however, that telescope owners should ignore Mars this month. The Red Planet lies extremely close to the double star Alpha^1 (α^1) and Alpha^2 (α^2) Librae on the morning of November 26. Mars, at magnitude 1.7, passes 2′ south of 5.2-magnitude Alpha^1 Librae and just 14″ — about four Mars diameters — south of magnitude-2.8 Alpha^2 Librae. Your best view of the event comes just after Mars rises — around 5:30 local time — which is a bit over two hours after closest approach from the East Coast of North America and five hours after closest approach from the West Coast. Even from western North America, however, the ocher-colored disk of Mars lies just a few arcminutes away from the white pinpoint of light Alpha^2 Librae.

This is the last good month in 1989 to view Uranus. Low in the southwest after sunset, Uranus shines at magnitude 5.8 and has a 3.5″-diameter blue-green disk. The planet is in conjunction with the Sun in late December and will return to the morning sky early next year.

ASTEROIDS IN THE EYEPIECE

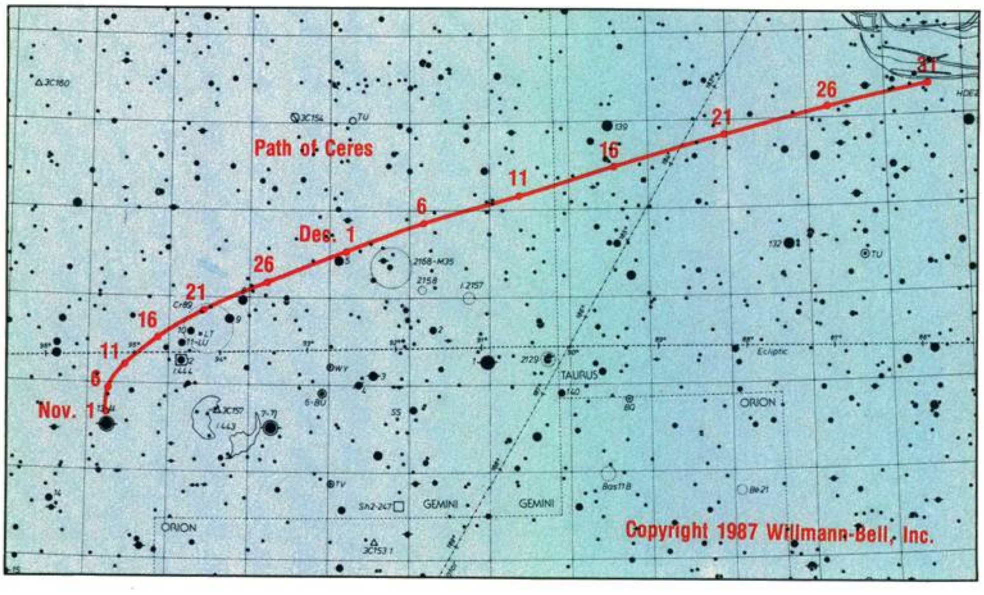
On the night of November 28/29, the magnitude 9.7 asteroid 115 Thyra reaches opposition in Perseus. Thyra is particularly interesting because its orbit brings it far into the northern sky.

The brightest asteroid this month is also the largest asteroid and the first one discovered — 1 Ceres. Ceres reaches opposition in mid-December, when it shines at magnitude 6.7, but it brightens from 8th to 7th magnitude this month and is easy to find in Gemini, about 5° west of Jupiter. Use the finder chart and the table of coordinates at right to locate Ceres during November and December. ☐

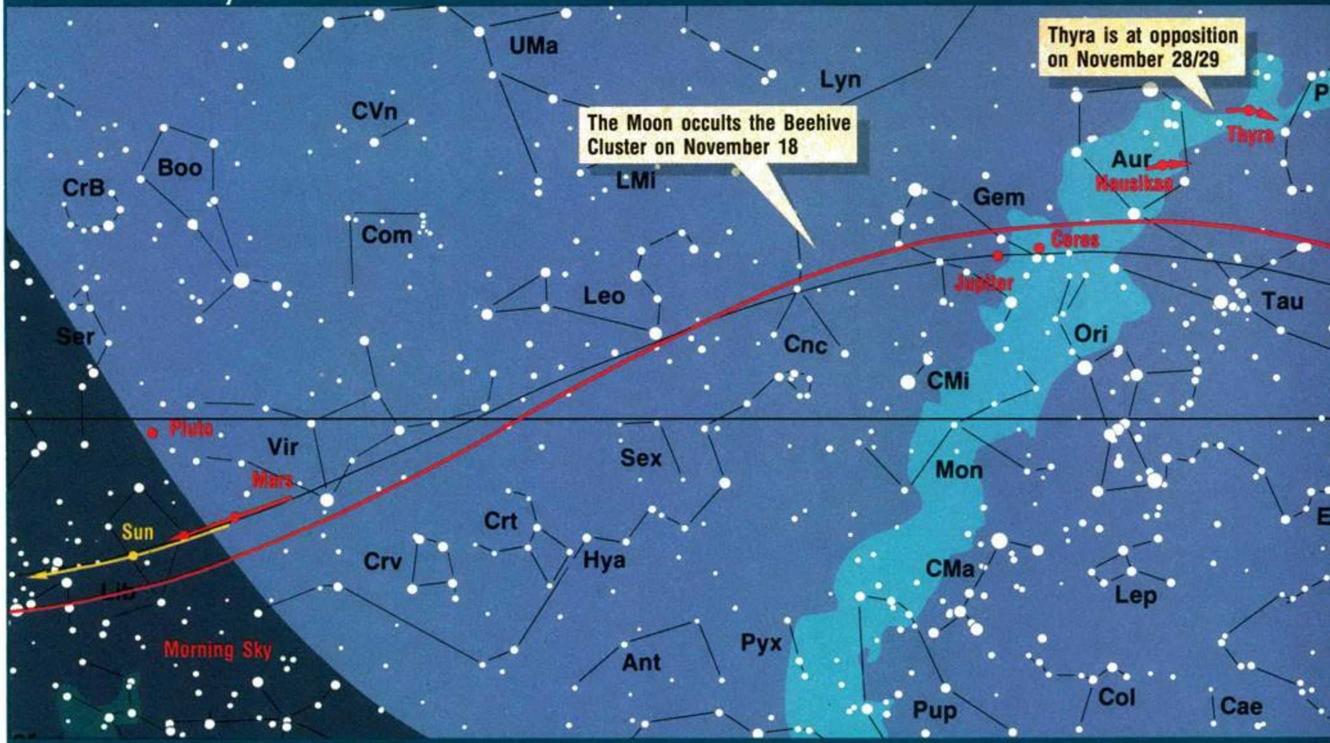
COORDINATES FOR CERES

Date	R.A. (2000)	Dec.
Nov. 1	6h23.3m	22°31′
Nov. 6	6h23.2m	22°47′
Nov. 11	6h22.4m	23°04′
Nov. 16	6h20.8m	23°22′
Nov. 21	6h18.5m	23°42′
Nov. 26	6h15.5m	24°03′
Dec. 1	6h11.9m	24°24′
Dec. 6	6h07.6m	24°45′
Dec. 11	6h02.9m	25°07′
Dec. 16	5h57.9m	25°27′
Dec. 21	5h52.6m	25°47′
Dec. 26	5h47.4m	26°06′
Dec. 31	5h42.2m	26°23′

ASTEROID CERES shines at 8th magnitude in Gemini during early November and then moves into Taurus and brightens to 7th magnitude in December. Positions are given for 0 UT.



The Solar System November 1989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Pyx
Ant
Hya
Sex
Crt
Crv
Vir
Lib
Ser
Pluto
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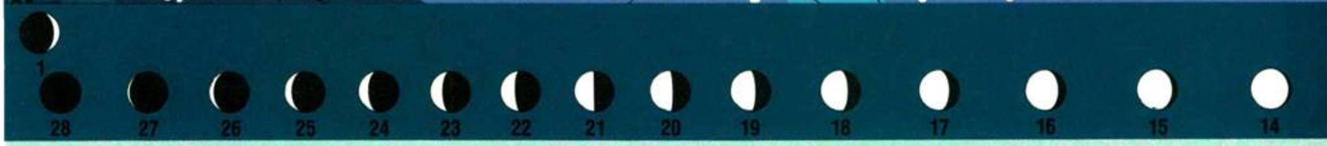
Sun
Jupiter
Ceres
Nausikaa
Thyra
Morning Sky

The Moon occults the Beehive Cluster on November 18

Thyra is at opposition on November 28/29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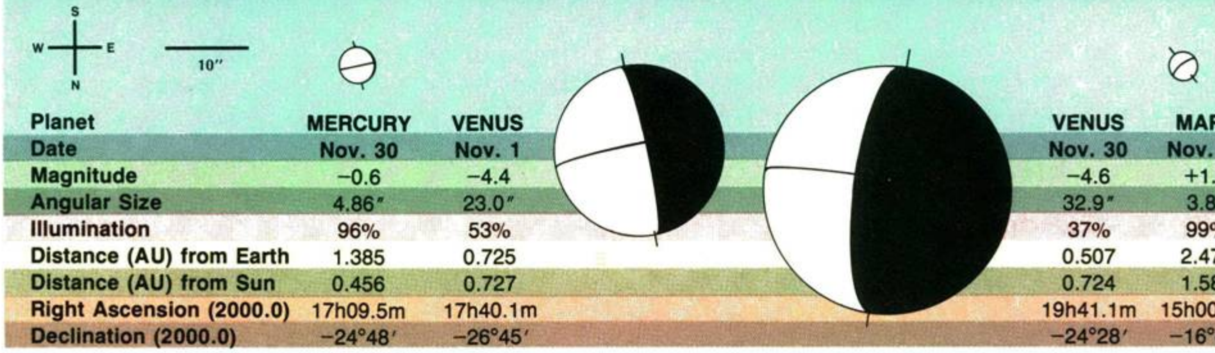
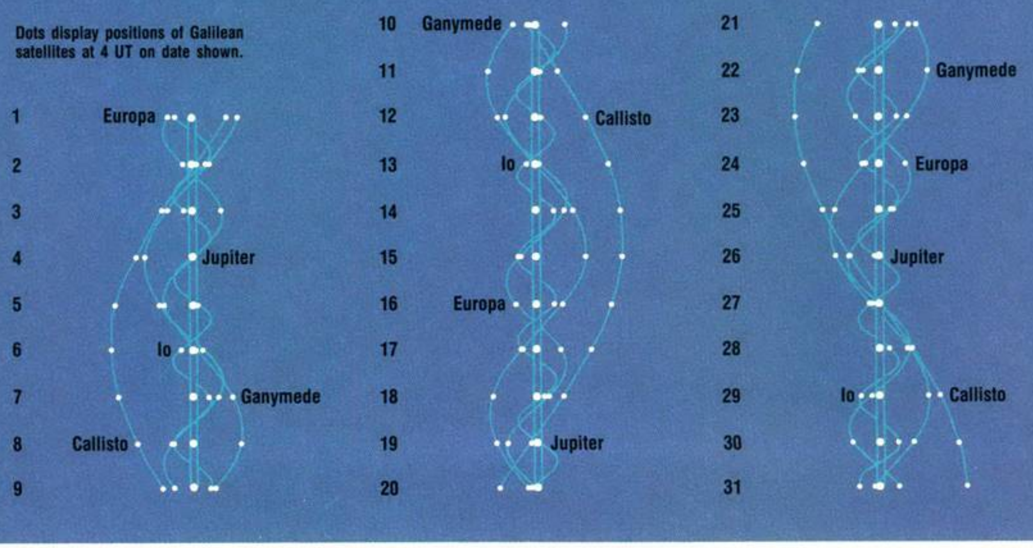
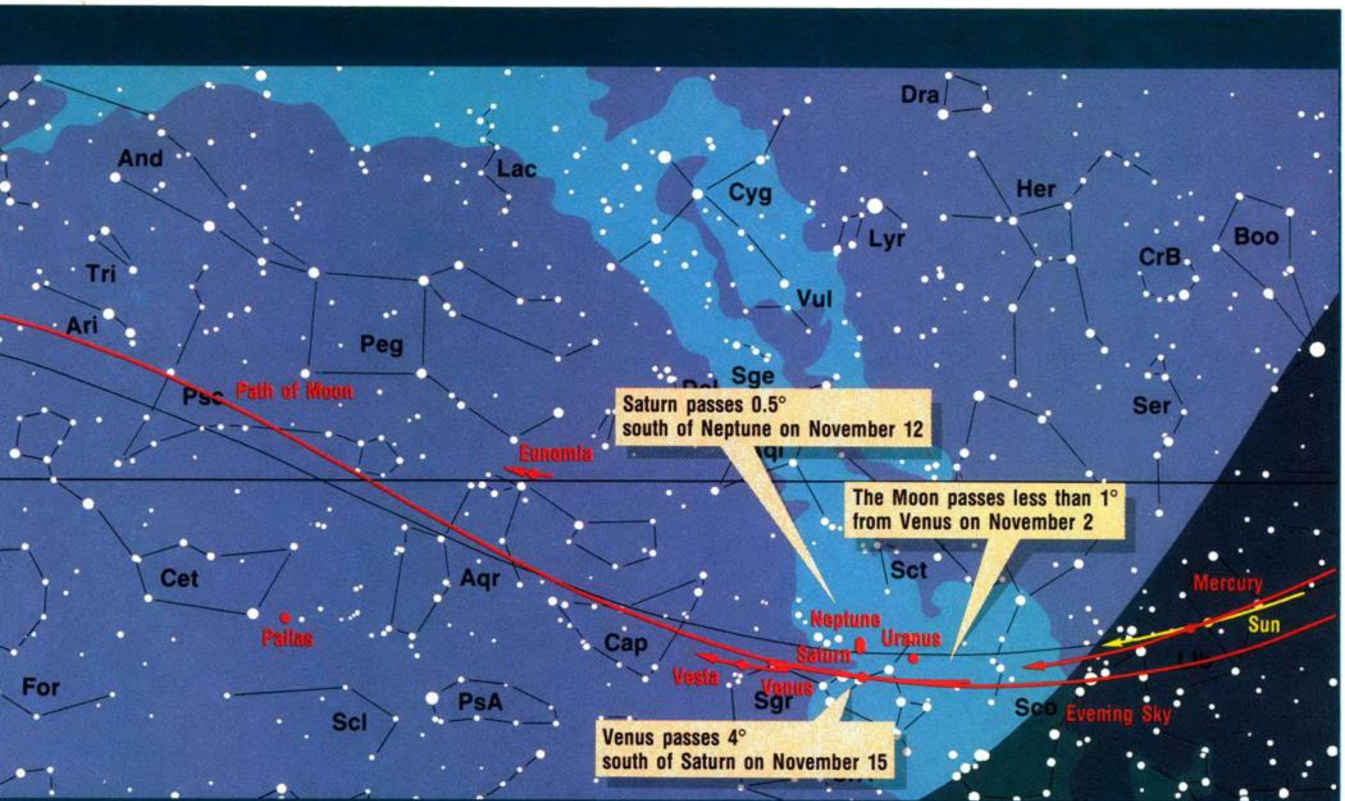


Planet	MERCURY	VENUS	VENUS	MARS
Date	Nov. 30	Nov. 1	Nov. 30	Nov. 30
Magnitude	−0.6	−4.4	−4.6	+1.6
Angular Size	4.86″	23.0″	32.9″	3.8″
Illumination	96%	53%	37%	99%
Distance (AU) from Earth	1.385	0.725	0.507	2.474
Distance (AU) from Sun	0.456	0.727	0.724	1.586
Right Ascension (2000.0)	17h09.5m	17h40.1m	19h41.1m	15h00.8m
Declination (2000.0)	−24°48′	−26°45′	−24°28′	−16°48′

Jupiter's Moons

Dots display positions of Galilean satellites at 4 UT on date shown.

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Cet
Aqr
Sct
Mercury
Sun
Pallas
Neptune
Uranus
Saturn
Cap
Vesta
Venus
Sgr
PsA
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Evening Sky
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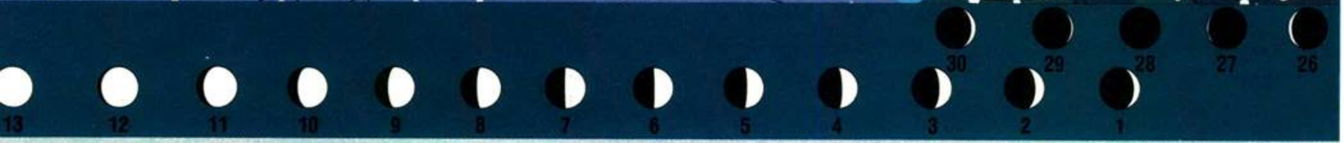
Saturn passes 0.5° south of Neptune on November 12

The Moon passes less than 1° from Venus on November 2

Venus passes 4° south of Saturn on November 15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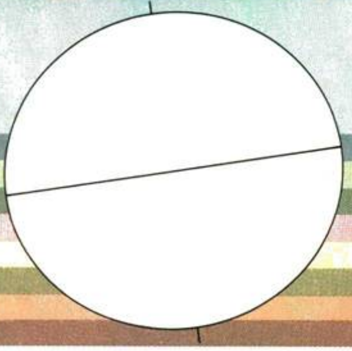
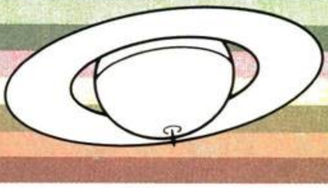
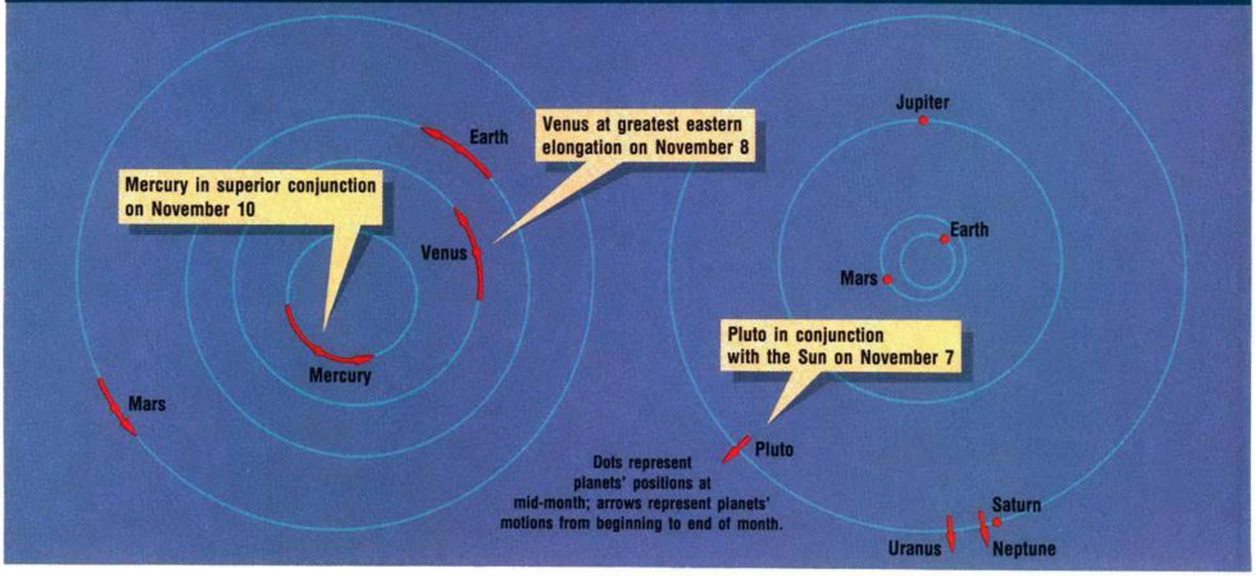




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Nov. 15	Nov. 15	Nov. 15	Nov. 15	Nov. 15
−2.6	+0.6	+5.8	+8.0	+13.8
44.6″	15.5″	3.5″	2.2″	0.1″
99%	100%	100%	100%	100%
4.417	10.667	20.113	30.867	30.602
5.134	10.030	19.372	30.212	29.656
6h45.7m	18h46.2m	18h14.1m	18h45.6m	15h09.8m
22°48′	−22°39′	−23°40′	−22°10′	−2°00′

The Planets in Their Orbits


Earth
Venus
Mercury
Mars
Jupiter
Earth
Mars
Pluto
Saturn
Uranus
Neptune

Venus at greatest eastern elongation on November 8

Mercury in superior conjunction on November 10

Pluto in conjunction with the Sun on November 7

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

THREE EASY PIECES

Enhance your telescope with a new finder scope, an observing tray, or a Dobsonian mount, all of which you can build yourself from inexpensive, readily available materials.

The Long-Play Dobsonian

by James Chen

I recently obtained a 10-inch f/4.5 Newtonian tube assembly, but to make the telescope usable I needed to build a sturdy mounting. Having read about Dobsonian mounts, I decided to make one myself.

The most exotic material used in a Dobsonian mounting is Teflon, which I found at several plastics warehouses in the area where I live. Teflon is the bearing pad on which a rocker box faced with Formica swivels; the low friction between the Teflon and Formica allows the mount to turn smoothly without any backlash.

Although finding Teflon was no problem, Formica was impossible to get at a reasonable cost. Local builders use prefabricated kitchen countertop assemblies, so no Formica cutouts were available at construction sites. Worse, hardware stores didn't carry small pieces of Formica at prices I could afford. I had to find a low-friction alternative to Formica.

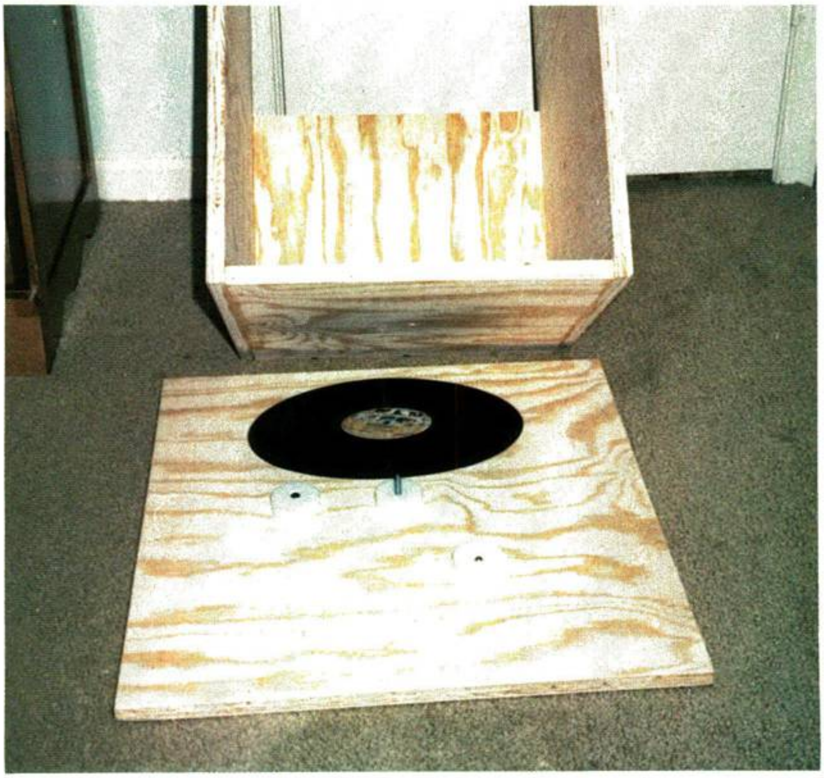
I decided to see how Teflon-on-bare plywood worked. It didn't. Then, in a stroke of inspiration, I put an old LP record between the Teflon and the plywood — and it worked!

Teflon-on-vinyl provided smooth movement with no backlash. The record was easy to install because it already had a hole in the middle. I didn't have to attach the record to the plywood because friction between the record and the plywood held it in place.

The rest of the mounting construction proceeded smoothly, or so I thought. To avoid taxing my limited carpentry skills, I attached the PVC closet flanges (used for the altitude bearings) directly onto the tube assembly. The flanges attach at the telescope's center of gravity with a 32mm eyepiece in the focuser. This was simple to do, but it gave me no way to adjust the scope's balance.

The telescope and mount worked fine with my standard eyepieces, but when I used my heavy 9mm and 13mm Nagler eyepieces I found I needed a counterweight because the telescope became unbalanced when I was viewing close to the zenith. Again, I had a problem demanding a novel solution. Because my eyepieces range widely in weight, I needed some means of varying the amount of counterbalancing. The conventional approach to the problem uses sliding weights, but this conflicted with the simplicity and low-cost aspects of Dobsonian telescopes.

My solution was to use hi-fi speaker magnets. I had three dome tweeters with burned-out voice coils left over from my days as a stereo salesman. Disassembling the speakers gave me three half-pound magnets. One speaker magnet had a center hole, which I used to bolt it to the telescope tube at the same height as the flange bearings and on the opposite side from the focuser. Depending on which eyepiece I use, I stick on one or two additional magnets to the base magnet.



AND WHEN YOU TURN THE SCOPE, it plays "Eleanor Rigby." An old LP record substitutes for a Formica bearing surface on James Chen's Dobsonian.

A Tray for a Celestron Tripod

by Edward C. Hoy

Three years ago, I bought a Celestron Super C8 telescope with a metal tripod. The scope and tripod have provided many stargazing thrills.

However, the Byers worm gear drive was powered by 110 volts. When I wanted to use a drive corrector with a 12-volt to 110-volt inverter and a 12-volt battery power source for observing in remote locations, I had to kludge together a system that involved a card table next to the telescope and wires dangling in the dark.

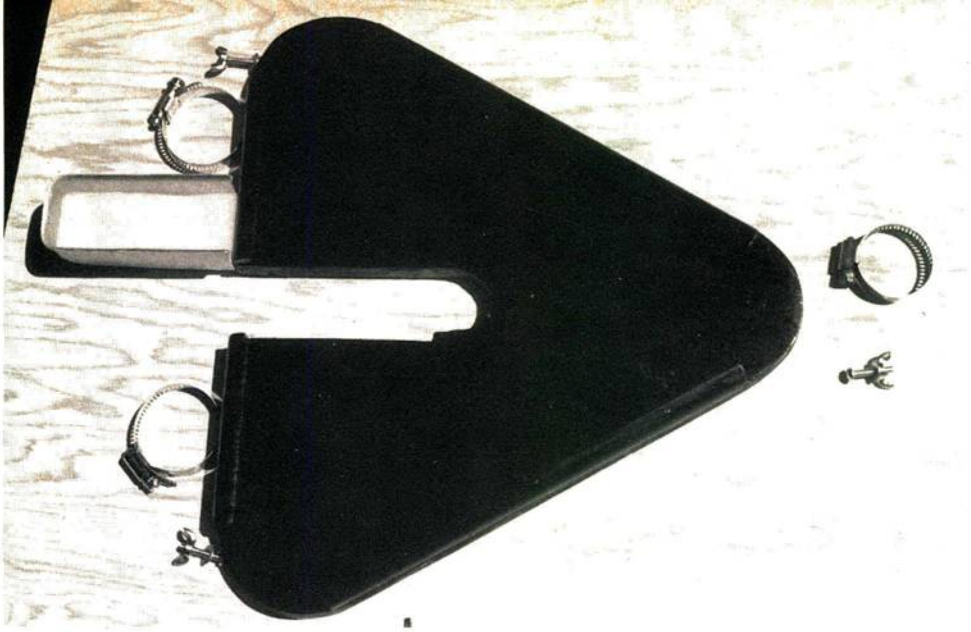
This worked after a fashion, but at a recent star party I was concerned that someone would trip over the wires running from the table to the telescope and tripod. Later models of the telescope provide some built-in functions, but that wasn't helping me.

The best solution was to attach a sturdy tray to the metal tripod. I called a dealer and inquired if Celestron made such an accessory tray. I was told that they did make a tray, but it was too small for the items I wanted to place on it. Furthermore, it fit only Celestron's wooden tripods. So I was left with a dilemma: continue with the makeshift arrangement or design and build a tray myself.

After some thinking, I came up with some requirements the tray had to satisfy. The tray had to be strong enough and large enough to hold a 12-volt Porta-Pac Battery, an Accutron Drive Control System with inverter and joystick hand control, plus extra eyepieces, and so on. It should attach quickly to the metal tripod with no interference from the center pole. The tray should also remove easily so that the tripod can be folded and stored with the tray support brackets still in place. I also wanted the tray to fasten to the three tubular legs so that the legs could be extended or retracted while the tray is still in place.

Also, the tray should be located conveniently high on the tripod for easy access, yet low enough to provide headroom for the 8-inch-high 12-volt Porta-Pac Battery. In addition to these requirements, the tray also had to be able to be built at home with readily available materials and a few common tools. The last "desirable" was the most important: it had to be inexpensive.

As you can see from the photos, the tripod tray came out very well. It's handy, practical, and my total material cost was about $12. A list of the parts you'll need is given in the diagram on page 72. Interested? Here's how to build it.



A HOME-BUILT TRAY made from simple materials neatly solved the problem of storing the electronics for Edward Hoy's Celestron telescope. Similar trays can be designed for any make of tripod.

Step 1. Lay out an 18-inch equilateral triangle on a piece of ¾-inch-thick plywood and cut it to size. Mark the center line of the slot (to be cut in step 3) by measuring 9 inches from two of the corners. (See diagram on page 72.)

Step 2. Lay out and round each corner of the triangle to a 1$\frac{1}{16}$-inch radius. (These round corners are needed to assemble and disassemble the tray from tripod.)

Step 3. Measure and mark a 1½-inch-wide slot, 6⅛ inches long as in the diagram, using the center line marked in step 1 as a reference. The slot should end in a 1½-inch diameter circle. (I cut out the slot with a saber saw using a scroll blade.) Now sand all the tray surfaces to smoothen them and remove sharp edges.

Step 4. From a 6-foot strip of half-inch quarter-round wood molding, cut the four tray edge pieces. (They keep accessories from sliding off the tray.) I cut mine so that they just fit the straight tray sides and end where the corner curves begin, but any length you prefer will suffice. Sand the pieces smooth and round the corners. Glue each piece to the edge of the tray with the round surface facing out (any wood [carpenter's] glue will do). For strength, add two small finishing nails per strip and drive in their heads flush with a nail-set.

Step 5. Set each angle bracket in a vise and open it up from 90° to 115°, using a protractor to get the angle just right.

Step 6. Spread the tripod legs to their maximum and slide the spreader bars that fasten to the center pole all the way down to the bottom of the pole. Position a bracket on one of the legs, 8¾ inches down from the casting at the top of the tubular part of the leg and mark the leg. Be sure each horizontal bracket arm points straight in toward the tripod's center pole; do the same for the other two legs.

Step 7. Using a screwdriver, completely open each of the six stainless steel auto hose clamps. Working one tripod leg at a time, hold the bracket to the mark on the tube leg, wrap the upper hose clamp around bracket and leg, and tighten firmly with a screwdriver. Make sure each bracket is properly aligned, then add the lower clamp and tighten it. Repeat the process for each of the three legs.

Align the screw part of the hose clamps so they do not protrude outwards, or you'll snag your leg when walking around the scope in the dark. Cut off any excess clamp material after tightening, and smooth the sawed edges with a file.

Step 8. Insert the tray between the legs below the brackets with the tray slot facing away from you. Push the tray slot around the center pole and tip the slot end of the tray up above the brackets while rotating it slightly to the left or right. Lift the near side above the last bracket and align it in position. Each tray corner should now be centered on the inside of each tripod leg. Now reach under the brackets, insert a pencil through the outer hole of one bracket, and mark the tray for a bolt hole. Repeat for each leg, then drill a 15/64-inch hole in each tray corner.

When you first insert and align the tray to mark the drill holes, improve the fit if necessary by slightly loosening the hose clamps to move the brackets up or down. Before you finally tighten the brackets in place, set a bubble level on the tray to ensure it's level. (But first be sure the tripod *itself* is level by checking the built-in bubble level in the wedge.)

Step 9. After drilling the tray, paint the tray and the clamp-bracket assembly on each tripod leg. I used two coats of black enamel. Let all the parts dry thoroughly before you reassemble them.

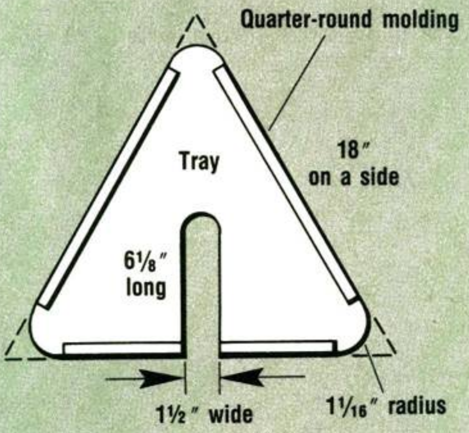
Step 10. To attach the tray to tripod, align the tray as described in step 8 with the tray holes over the bracket holes and bolt them together. The tray holes are designed to be a little larger than the bracket holes because a slightly sloppy fit helps make alignment go quicker. Note that when the tray is removed, the tripod folds in all the way without interference from the clamps and brackets (which always remain attached to the tripod legs).

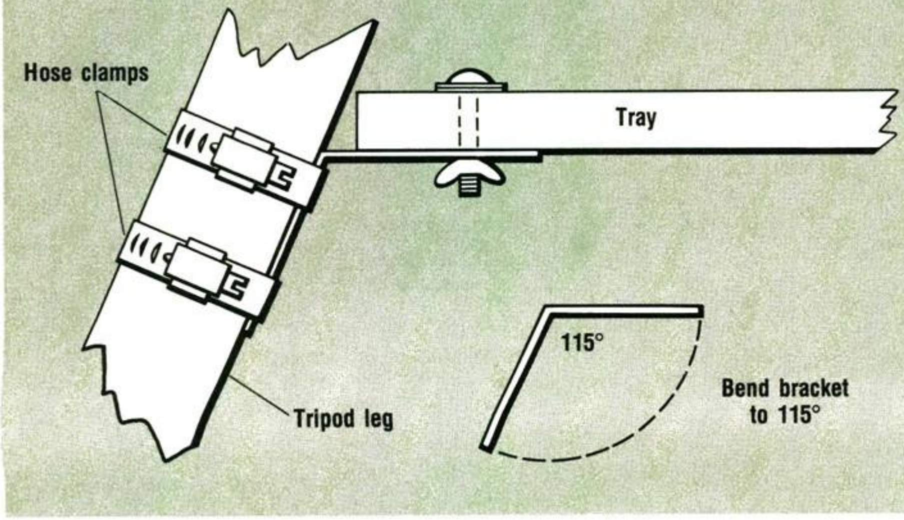
There are two additional simple options you might find helpful. Fashion a simple box that slips into and fills the slot when the tray is in place; lay a strip of foam rubber in the bottom and use it for eyepieces and filters. A single-row metal ice cube tray that I cut to length was ideal.

Also, I cut two small strips of Velcro adhesive and used them to hang my drive corrector joy-stick box on one flat vertical end of the wedge and my small observer's flashlight on the other end of the wedge.

Parts List for Tripod Tray

- one ¾″ plywood sheet, 18″ square
- three 1½″ steel angle brackets
- three #8-32 roundhead machine bolts, 1″ long, with flat washers and wing nuts
- six stainless steel auto radiator hose clamps, range: 1¼″ to 2¼″
- one 6′ strip of quarter-round wood molding
- one small can of black acrylic latex enamel





Build a PVC-Pipe 50mm Finder

by Charles Cappa

As long as I've owned a telescope, I've wanted a 50mm finder, but frankly I never could afford to spend $75 or more for one. While thumbing through a surplus equipment catalog one night, I came across a 52mm achromat lens for $9.50. I thought to myself, for that price why not try building one?

The lens for the scope is item 1722 from Jerryco, Inc., (601 Linden Place, Evanston, IL 60202; phone (312) 475-8440). The tube assembly is made of common PVC plumbing parts found at any plumbing supply store.

The parts list is shown in the photo at right; this finder is designed for either straight-through or right-angle viewing with a star diagonal. If you choose to make the right-angle version only, skip the sink pipe and flange.

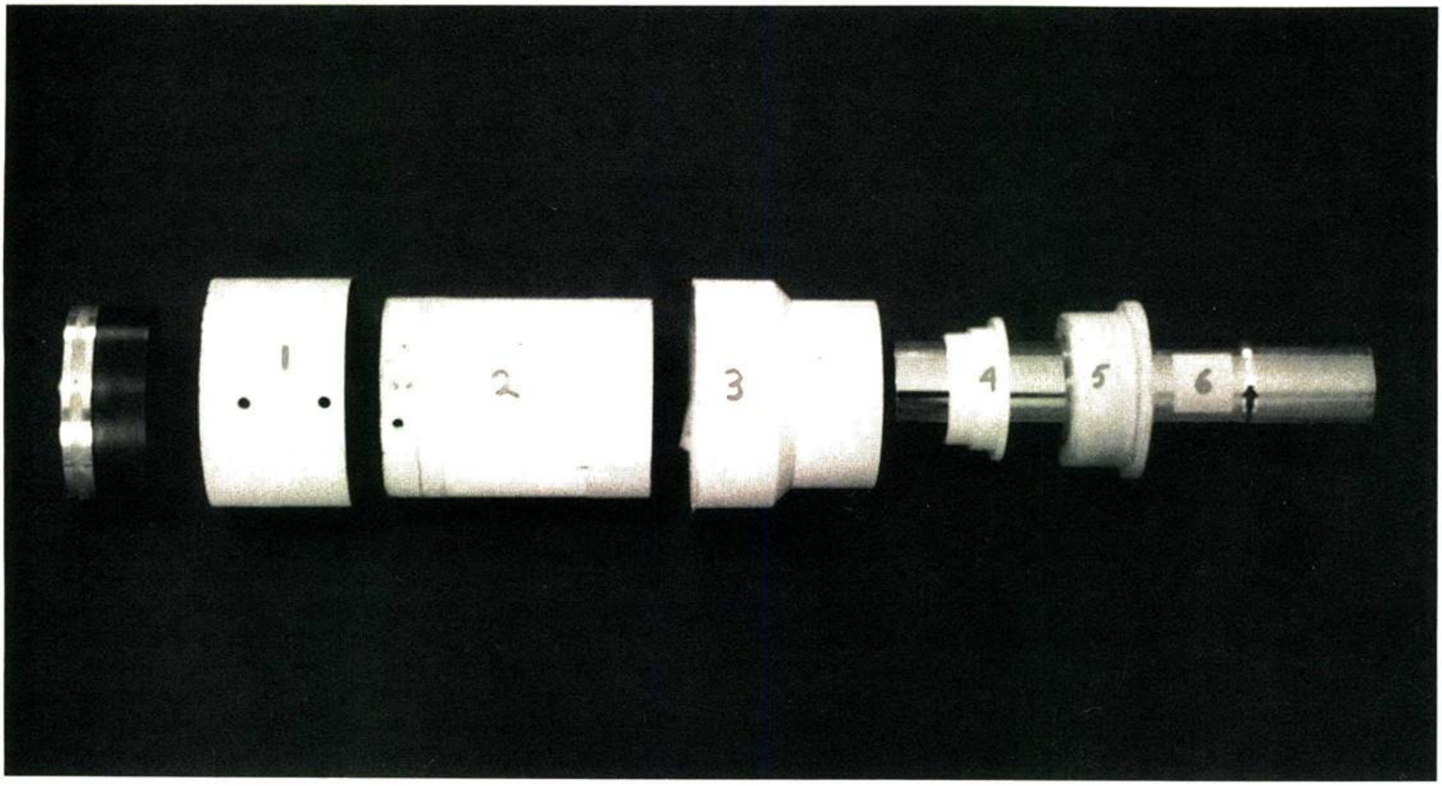
At the hardware store, pick up a #29 bit, a #8-32 tap, four #32 Allen head screws (two 5/16 inch long and two ¼ inch long), masking tape, 18 inches of half-inch-wide Velcro (you need only the fuzzy part), flat black spray paint, and your choice of a finishing color.

The scope consists of three basic parts: the 2-inch coupler (which will be your dew cap and house your lens), the 2-inch PVC pipe (the body), and the reducer that houses the focuser. It is a good idea to assemble the finder parts "dry" — without glue — to check how the parts fit.

Before you start building, spray paint all the inside surfaces of the parts, including the sink pipe, flat black to reduce reflections. Wrap masking tape around the parts to be cut and mark them carefully. The PVC and pipe can be cut with an ordinary hacksaw; take care to make the cuts straight to insure proper collimation.

The first part to assemble is the focuser. To do this, you need the reducer, flange, bushing, sink pipe, hacksaw, sandpaper, and PVC glue. Building the finder so that it will work with either straight-through or right-angle viewing is outlined in the first two steps. If you want just the right-angle version, skip to step three and begin there.

Step 1. Sink pipe focus tube. Cut ⅜ inch off both ends of the 6-inch sink pipe, then cut a T-shaped slot in the wide end of the pipe. Bend the tabs slightly inward so they will grip the finder's eyepiece firmly and file off all burrs. Next, sand the inside of the PVC flange so the sink pipe slides



Jerryco lens #1722 | **2″ PVC coupler (1)** | **2″ PVC pipe (2)** | **1½″ by 2″ PVC reducer (3)** | **1¼″ tubular flange (4)** | **1½″ by 1″ PVC bushing (5)** | **1¼″ by 6″ thin wall sink pipe (6)**

nicely into it, but be careful not to sand it too much. You need some friction to hold the sink pipe at focus no matter where the finder is pointing.

Step 2. Gluing the flange inside the reducer. Slide the flange (oriented as in the photograph) approximately 2 inches onto the sink pipe's smaller end. Apply pipe glue to the underside of the wide rim of the flange. Place the reducer, wide end down, on two blocks of wood of equal height. (The blocks raise the reducer so the sink pipe can be inserted far enough.) When you insert the sink pipe with the flange into the reducer, make sure, before the glue sets, that the sink pipe parallels the sides of the reducer. Let the assembly dry and apply a second coat of glue for a good bond.

Step 3. Bushing. Cut half an inch off the small end of the bushing and sand it smooth. Glue a strip of Velcro inside the bushing to give a snug, sliding fit for the sink pipe or star diagonal. Slide the bushing into the narrow end of the reducer, making sure it sits flush to the end of it. When you are satisfied with the fit, glue the bushing in place.

Step 4. Figuring tube length. After your focuser end is finished, it's time to figure the length of the 2-inch PVC pipe tube. My pipe length measured 2¾ inches, but this length could vary due to a different objective lens or eyepiece.

Fashion a makeshift cardboard tube about 3 inches long, insert it into your reducer-focuser assembly, and tape the objective lens onto the other end. Using a star diagonal, focus on the Moon or a bright star. Trim small amounts off the tube until you arrive at a length that gives optimum focus adjustments in either direction with your intended eyepiece(s). This length should also work with the sink pipe focuser.

Mark the 2-inch PVC tube the same length as the cardboard tube and cut it square. I was able to make straight cuts using a hacksaw simply by taking my time and going around the perimeter cutting through gradually. Sand all surfaces smooth.

Step 5. Two-inch dew cap coupler. Measure half an inch down from one end of the coupler and make two drilling marks on opposite sides of the coupler, 180° apart. Drill through the marks with the #29 bit; I call these "lens holes" because they hold the objective lens in place. On the other end of the coupler, make two more marks, this time ¼ inch from the end, and drill them through. These are the "tube holes" because they attach to the tube.

Wrap one or two turns of masking tape around one end of the 2-inch pipe. Make several marks around the perimeter, ⅜ inch from the end; these are locator marks. Slide the coupler ("tube hole" first) over the tube as far as the marks and make sure it sits level. Now drill through the tube holes into the tube, but don't go all the way through.

Tap all four holes with the #8-32 tap. Screw in the two ⁵⁄₁₆-inch-long #32 setscrews into the tube holes and lock the coupler into the tube.

To install the lens, slide the silver rim off the front of the lens and drop the lens into the coupler, making sure it sits flat against the end of the tube. Slip the silver ring back over the lens and center it. Run your last two ¼-inch setscrews into the top half of the coupler while you apply gentle pressure to the lens from the front as you tighten the screws.

Step 6. Mating the reducer-focuser to the tube. Sand the back end of the 2-inch pipe so the reducer slides over it as far as it can go. Secure it to the pipe either by gluing it in place or by drilling an additional hole through the reducer and pipe and tapping an additional setscrew. (This completes the construction and assembly.)

Step 7. Mounting options. I tapped an additional ¼-20 hole into the base of the reducer so that I could mount it on any standard tripod; thus my finder (with a 45° image erector) is a great spotting scope. To mount it on my 6-inch telescope, I picked up a set of Meade guidescope brackets (product #07430) at a swap meet.

Is it versatile? Well, you're in for another surprise. Try hooking it up to your 35mm camera — mine makes a neat telephoto lens. ☐

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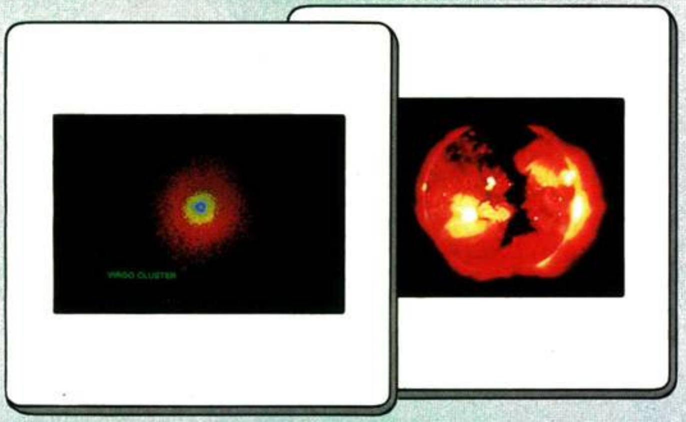

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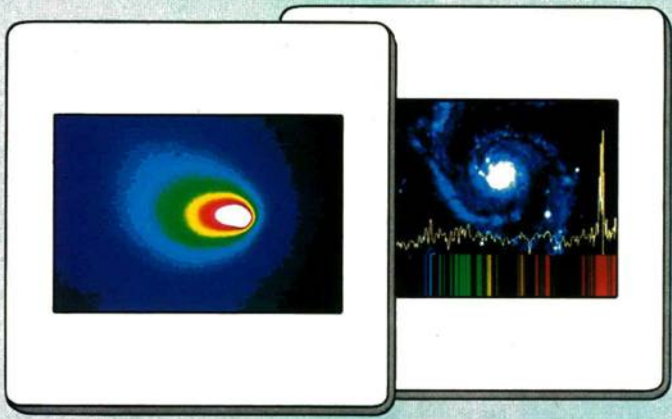

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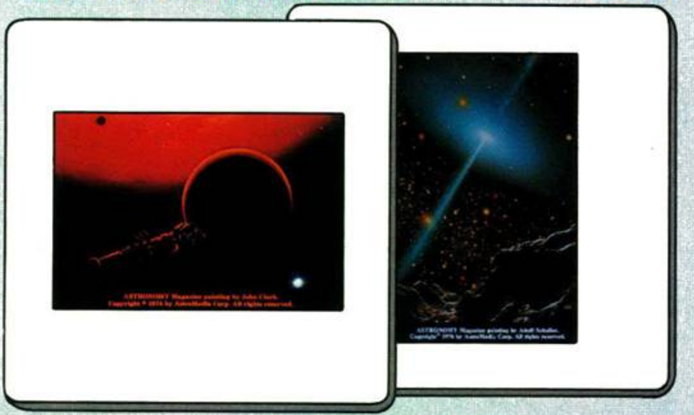
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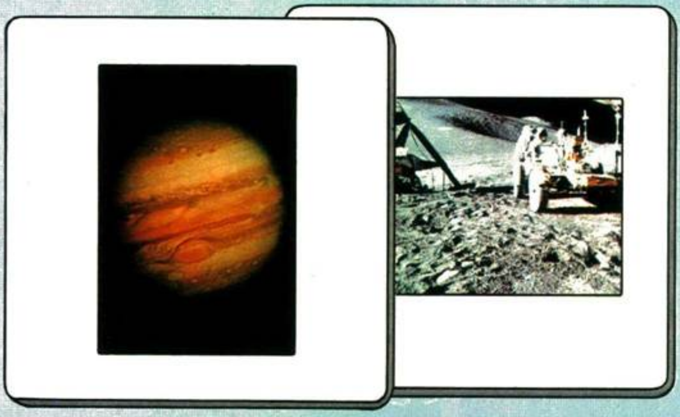

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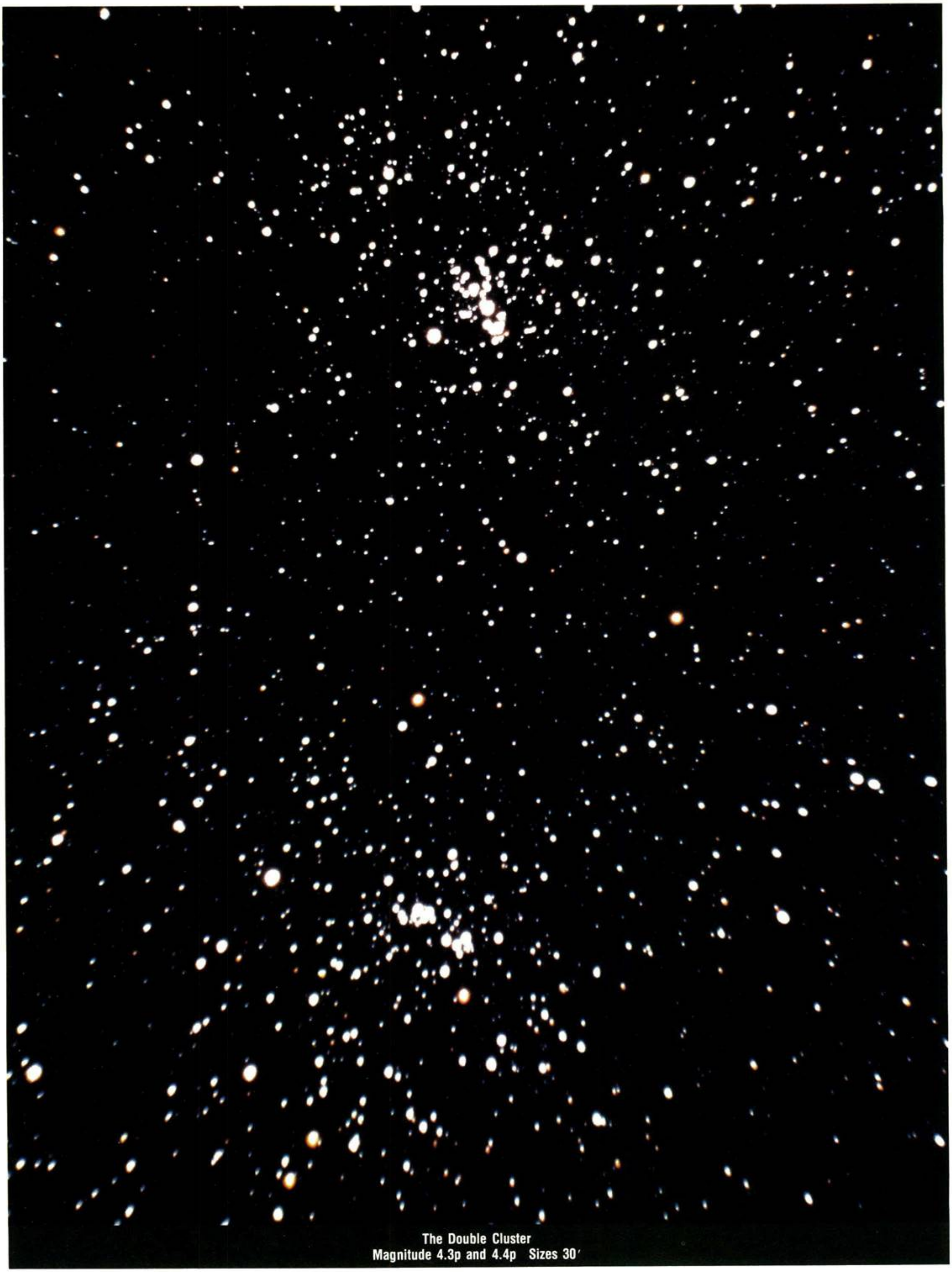


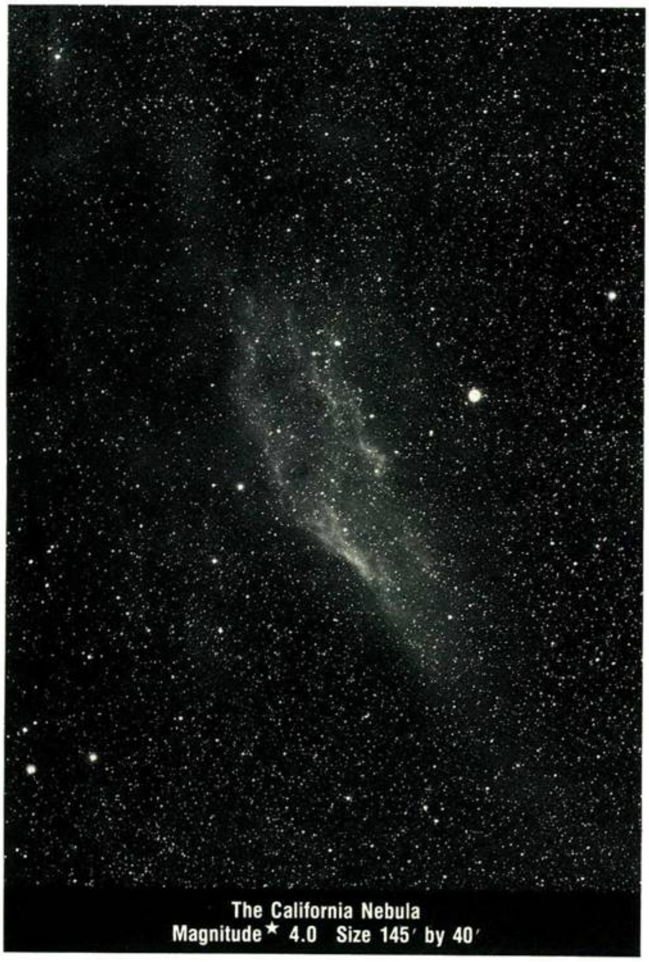
The Double Cluster
Magnitude 4.3p and 4.4p Sizes 30′

Treasures of the Winter Milky Way

Perseus and Cassiopeia in the northern sky offer a bounty of bright objects for observers with nothing more than binoculars.

by David J. Eicher

Every cold, crisp autumn night that pulls me out under the stars attracts me to one special place in the sky. It's an area densely stocked with impressive deep-sky objects. The region of sky encompasses the constellations Perseus and Cassiopeia and represents the richest region of the winter Milky Way. When we look toward Perseus and Cassiopeia, we are gazing through an outer spiral arm, the Perseus arm, toward the edge of our Galaxy's disk. We're looking into the Galaxy's plane of rotation — the space that we are slowly rotating toward. I start an annual reconnoitering of this wondrous area by simply gazing up at the Double Cluster in Perseus, a double patch of hazy light to the naked eye. The mystery and sense of remoteness inspired by the Double Cluster soon has me operating at full tilt with my telescope.



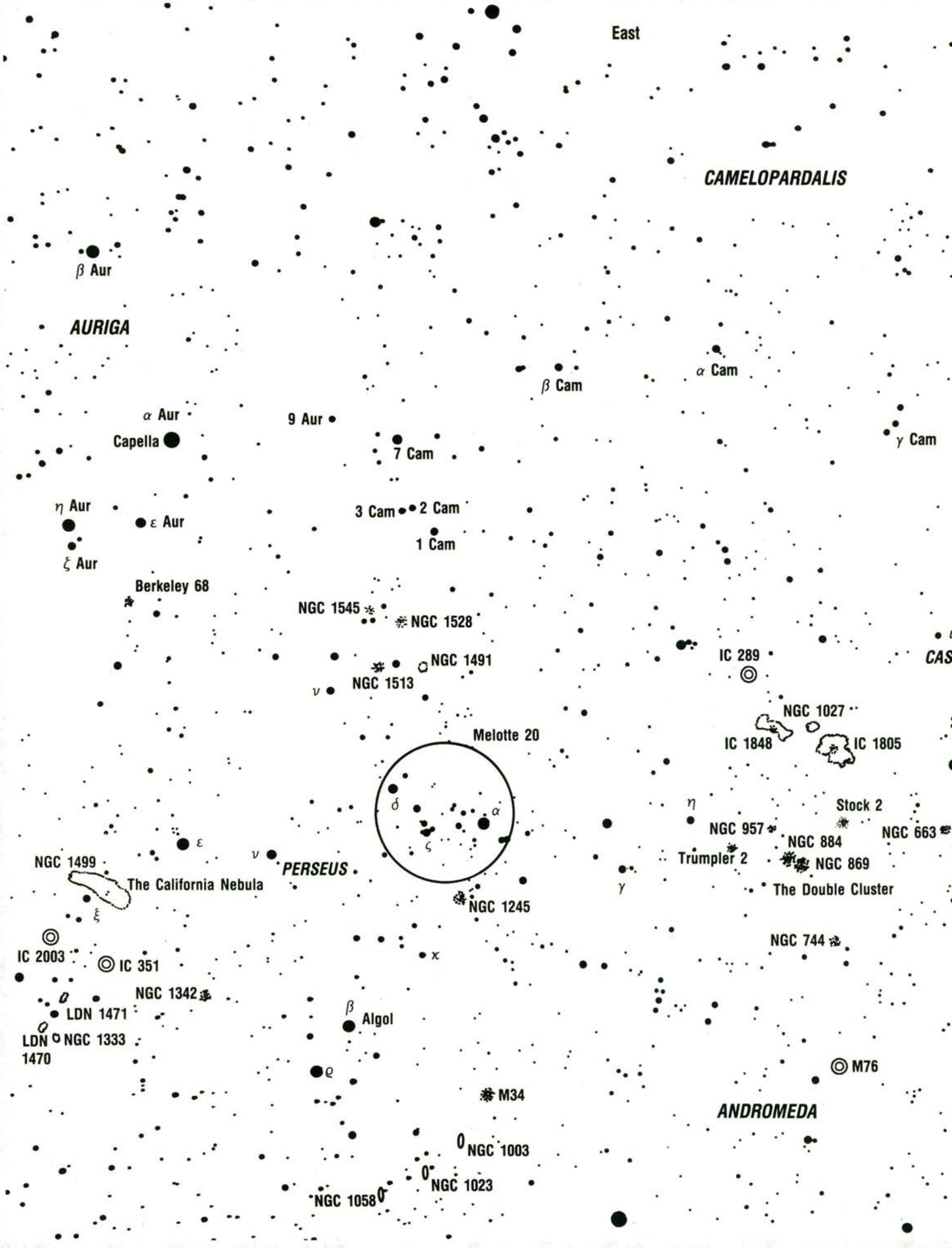
The California Nebula
Magnitude★ 4.0 Size 145′ by 40′

The **Double Cluster** in Perseus serves as a good object for testing a night's transparency. Composed of two large and bright open clusters, the Double Cluster is one of the brightest deep-sky objects in the sky. From a reasonably dark suburban or rural site, the Double Cluster is immediately obvious to the naked eye, appearing as a fuzzy barbell between the constellations of Perseus and Cassiopeia. If the cluster is not easily visible, the sky is not transparent enough for good observing.

Telescopes in the 2-inch to 6-inch range show the Double Cluster's western component (NGC 869) and eastern component (NGC 884) as roughly equivalent: each is a sparkling disk of tiny blue-white stars nearly as large as the Full Moon. Viewing the Double Cluster (and other big open clusters) with low power generally provides the most pleasing scene. Clusters appear as clusters when magnifications are low enough to surround them with empty sky. If you magnify them too much, clusters appear to be merely rich backgrounds of stars evenly spread across the field of view. A magnification between 20x to 40x is best for viewing big open clusters.

In large telescopes the Double Cluster comes alive. Each cluster contains at least 150 stars arranged in haphazard patterns — curving chains, clumps, pairs, triangles, and straight lines. (Modern studies identify two hundred stars in NGC 869 and 150 in NGC 884, although each cluster undoubtedly contains additional members.) The brightest stars in the clusters glow at magnitudes 6.6 (NGC 869) and 8.1 (NGC 884). Most of the brightest stars appear pure white or bluish white in color. However, a noticeable few have a yellowish or golden orange tinge. These varied colors help to give the Double Cluster a jewel-like quality.

After poring over the Double Cluster, nudge your telescope about 4° north and 1° east and you'll come upon a big, bright cluster in Cassiopeia, IC **1805** (Melotte 15). Often overlooked because of its exclusion from the Messier and NGC catalogs, IC 1805 is nonetheless quite an impressive object. Consisting of forty stars tucked into a diameter of 22′, this cluster is an easy object for binoculars and small scopes. The brightest individual star glows at magnitude 7.8, and the group's overall magnitude is 6.5 — at the limit of naked-eye visibility from an exceptionally dark site. If you sweep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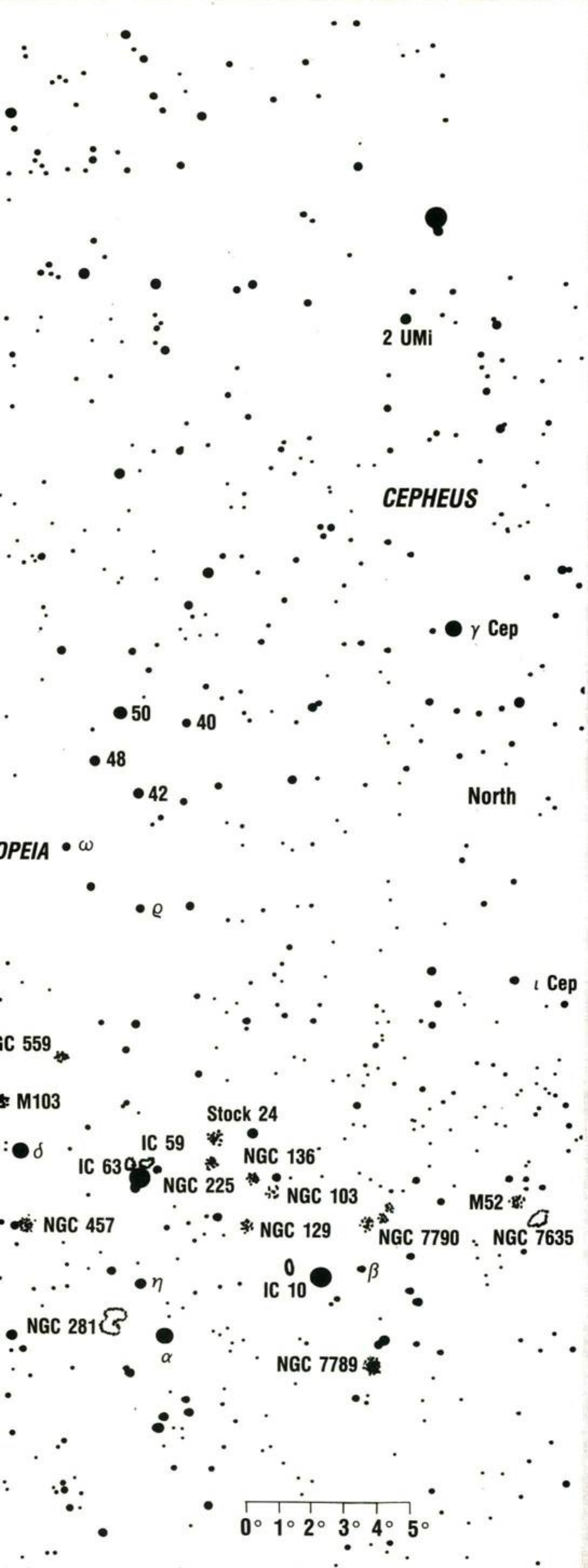
NGC 1003
NGC 1023
NGC 1058



Deep-Sky Objects in Perseus and Cassiopeia

Object	Type	R.A. (2000.0) Dec.	Mag.	Size	N★
Berkeley 58	oc	0h00.2m +60°58′	9.7	8′	30
IC 10	eg	0h20.4m +59°18′	10.3	5.1′x4.3′	—
NGC 103	oc	0h25.3m +61°21′	9.8	5′	30
NGC 129	oc	0h29.9m +60°14′	6.5	21′	150
NGC 136	oc	0h31.5m +61°32′	—	1.2′	20
NGC 147	eg	0h33.2m +48°30′	9.3	12.9′x8.1′	—
IC 63	ern	0h59.5m +60°49′	—	10′x3′	2.5v
NGC 457	oc	1h19.1m +58°20′	6.4	13′	80
NGC 559	oc	1h29.5m +63°18′	9.5	4.4′	60
M103	oc	1h33.2m +60°42′	7.4	6′	25
M76	pn	1h42.4m +51°34′	12.2p	65″	17.0
NGC 663	oc	1h46.0m +61°15′	7.1	16′	80
NGC 744	oc	1h58.4m +55°29′	7.9	11′	20
Stock 2	oc	2h15.0m +59°16′	4.4	60′	50
NGC 869	oc	2h19.0m +57°09′	4.3p	30′	200
NGC 884	oc	2h22.4m +57°07′	4.4p	30′	150
IC 1805	en	2h33.4m +61°24′	—	60′x60′	—
NGC 957	oc	2h33.6m +57°32′	7.6	11′	30
Trumpler 2	oc	2h37.3m +55°59′	5.9	20′	20
NGC 1003	eg	2h39.3m +30°09′	11.5	5.4′x2.1′	—
NGC 1023	eg	2h40.4m +39°04′	9.5	8.7′x3.3′	—
M34	oc	2h42.0m +42°47′	5.2	35′	60
NGC 1027	oc	2h42.7m +61°33′	6.7	20′	40
NGC 1058	eg	2h43.5m +37°21′	11.5	3.0′x2.9′	—
IC 1848	en	2h51.3m +60°25′	—	60′x30′	—
IC 289	pn	3h10.3m +61°19′	12.3p	34″	15.9
NGC 1245	oc	3h14.7m +47°15′	8.4	10′	200
Melotte 20	oc	3h22.m +49°	1.2	185′	50
NGC 1333	rn	3h29.3m +31°25′	—	9′x7′	9.5
NGC 1342	oc	3h31.6m +37°20′	6.7	14′	40
LDN 1470	dn	3h44.0m +31°47′	—	100′x70′	—
IC 351	pn	3h47.5m +35°03′	12.4p	7″	14.8
LDN 1471	dn	3h48.0m +32°54′	—	22′x9′	—
IC 2003	pn	3h56.4m +33°52′	12.6p	7″	16.5v
NGC 1499	en	4h00.7m +36°37′	—	145′x40′	4.0
NGC 1491	en	4h03.4m +51°19′	—	3′x3′	11
NGC 1513	oc	4h10.0m +49°31′	8.4	9′	50
NGC 1528	oc	4h15.4m +51°14′	6.4	24′	40
NGC 1545	oc	4h20.9m +50°15′	6.2	18′	20
NGC 1579	rn	4h30.2m +35°16′	—	12′x8′	12

Object: Designation in Messier, NGC, or other catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude of object unless followed by a p (photographic magnitude). **Size:** Diameter in arcminutes or arcseconds. **N★**: Number of stars in cluster, brightness of illuminating star (nebulae), or brightness of central star (planetary nebulae). V following magnitude denotes variability.

Open Cluster NGC 457
Magnitude 6.4 Size 13′

around IC 1805 at low power using a telescope of 8-inches or larger aperture, you may see traces of very faint, soft nebular light. This is light from an emission nebula surrounding the cluster that measures 60′ across. Like the material in the Orion Nebula, this material is coalescing to form the stars in the central cluster. Although this nebula is difficult to observe, it can be photographed on red-sensitive film with relative ease.

Just 2° southeast of IC 1805 lies another giant complex of star cluster and emission nebula, **IC 1848**. The star cluster IC 1848 contains ten stars of magnitude 7.1 and fainter in an area only 12′ across. It is an attractive specimen for binoculars and small telescopes. The emission nebula IC 1848 is shaped like a squashed rectangle spanning 60′ by 30′. The nebula's surface brightness is rather low, making it visible only with averted vision in an 8-inch telescope — and then only on very dark nights. IC 1805 and IC 1848 offer a rare comparison of two similar star-forming regions located at approximately the same distance (2.2 kiloparsecs) and positioned near each other in the sky. IC 1848 is fainter and has only a small star cluster because it is younger than IC 1805 and hasn't had as much time to produce new stars.

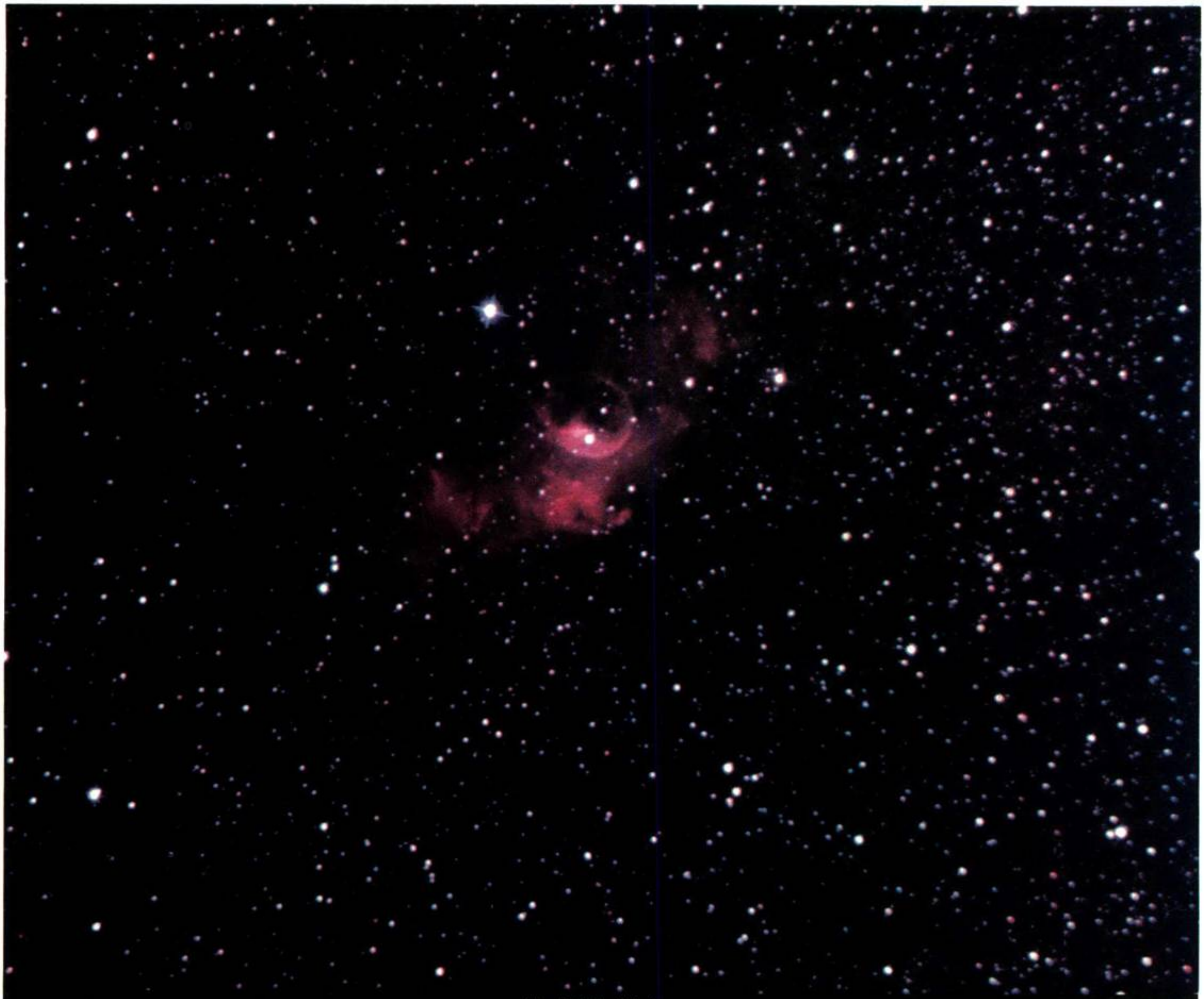
After viewing IC 1805 and IC 1848, drop back to the Double Cluster and continue moving your scope southwest. You'll encounter the 5th-magnitude star 4 Persei and then Phi (ϕ) Persei, a 4th-magnitude bluish white variable star. A move 1° north of this star will center your telescope on one of the most beautiful planetary nebulae in the sky, **M76** (NGC 650-1).

Often called the Little Dumbbell Nebula because of its resemblance to M27 in Vulpecula, M76 is revered by many observers as one of the faintest and most challenging Messier objects, a reputation it well deserves. M76 has the two important characteristics that make deep-sky objects challenging: a large diameter (65″) and a dim magnitude (photographic magnitude 12.2). Together, these give M76 a low surface brightness that makes the object appear dim no matter how much aperture you throw at it. To ensure a good view of M76, wait for a dark, moonless night with steady seeing and excellent transparency.

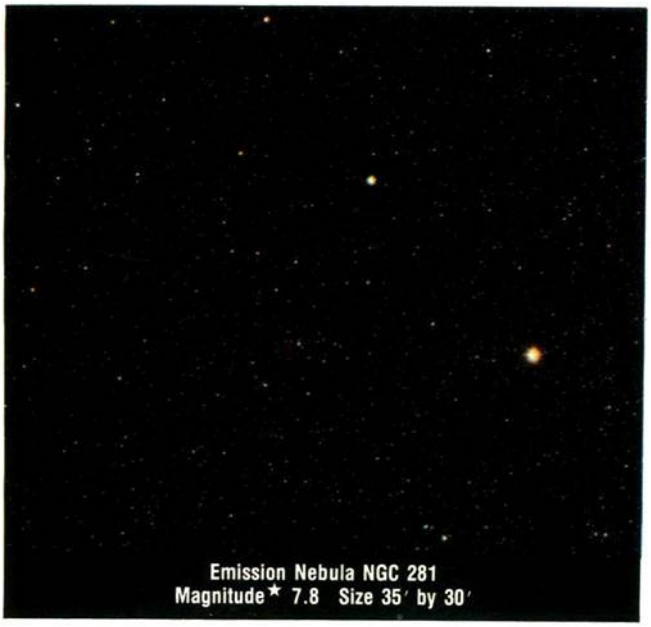
As you inch your telescope up toward the familiar W-shaped pattern of Cassiopeia, you'll encounter many bright deep-sky objects. Two small, attractive star clusters lie between Epsilon (ε) and Delta (δ) Cassiopeiae, the two easternmost stars in the W. **M103** (NGC 581) is a smattering of faint stars held within a diameter of just 6′. Altogether, twenty-five stars of magnitude 10.6 and fainter form this group. Two degrees east and a few arcminutes north of M103 lies a larger, brighter cluster. **NGC 663** spans 16′ and holds eighty stars of magnitude 8.4 and fainter within its gravitational grasp. The total magnitude of NGC 663 is 7.1; M103's is 7.4.

The rich cluster **NGC 559** lies 3° north of M103. This unusual cluster has an overall magnitude of 9.5 and is comprised of light from sixty stars glowing at magnitude 10.6 and fainter. All of these faint stars are packed into a diameter of 4.4′, making this group appear as luminescent buckshot punched through the dark background of the sky. As you compare these clusters, consider how the concentrations, colors, and brightnesses of the stars vary. Do the clusters appear differently at different magnifications?

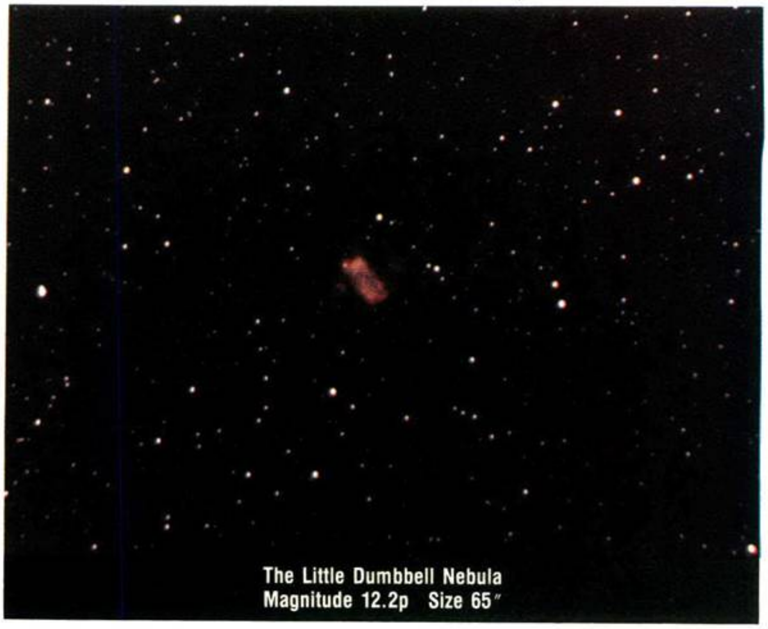
One of the most unappreciated open clusters, **NGC 457**, lies 3° south of Delta Cassiopeiae, nearly directly



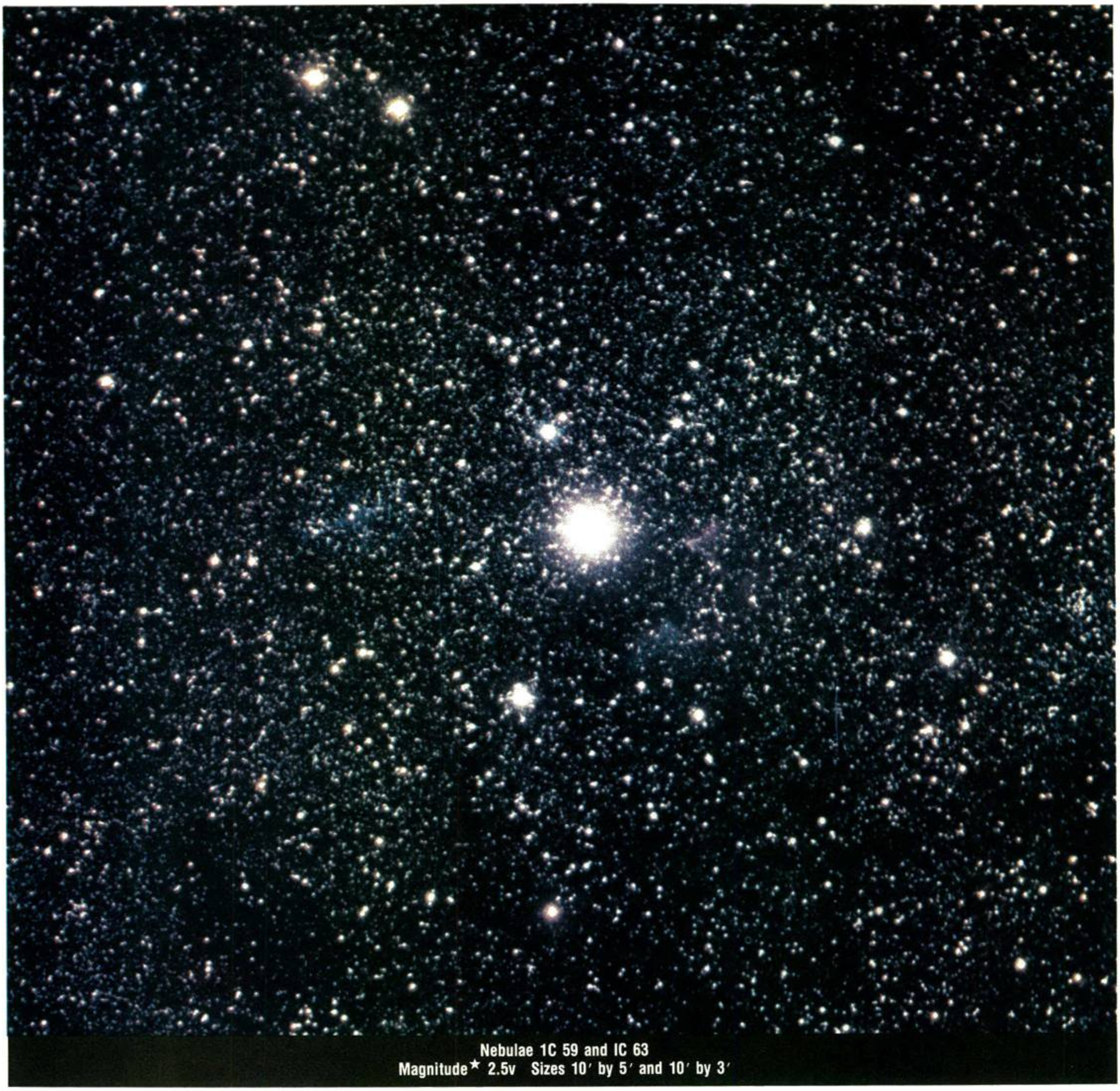
The Bubble Nebula
Magnitude★ 6.9 Size 15′ by 8′



Emission Nebula NGC 281
Magnitude★ 7.8 Size 35′ by 30′



The Little Dumbbell Nebula
Magnitude 12.2p Size 65″

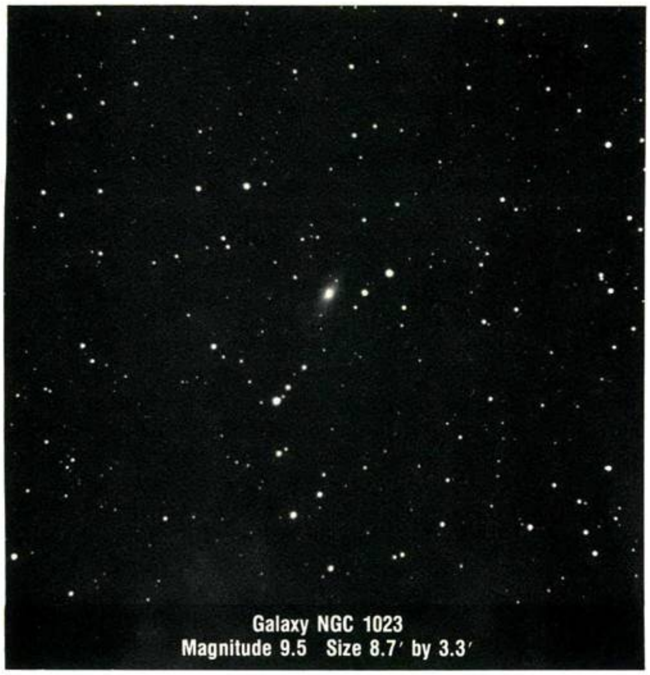


Nebulae IC 59 and IC 63
Magnitude★ 2.5v Sizes 10′ by 5′ and 10′ by 3′

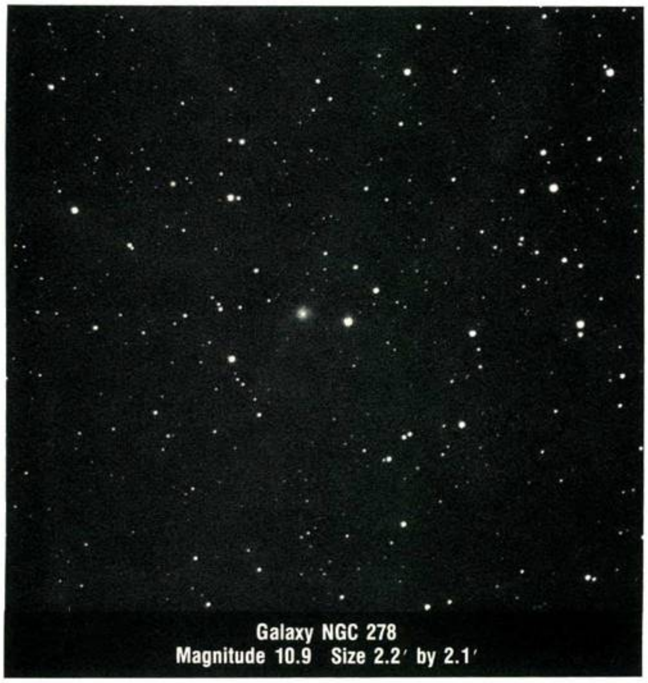
behind the ruddy, 5th-magnitude star Phi (ϕ) Cassiopeiae. The bright star Phi and a slightly dimmer star form what look like owl eyes, and the pattern of a few dozen bright stars that make up the torso, wings, and legs is striking. NGC 457's unmistakable shape takes me back to a night in 1979 when I looked at this cluster and the pattern of stars was so distinctive that I began calling it the "Owl Cluster." Some eighty stars of magnitude 8.4 and fainter make up the Owl Cluster, giving it a total magnitude of 6.4 spread over 13′. This object is beautiful in binoculars and small telescopes and requires a wide field with large telescopes. Astronomers debate about whether or not Phi Cassiopeiae is a physical member of the group. If it is, because of the cluster's distance of 2.8 kiloparsecs, it is one of the most luminous stars known.

The erratic variable star Gamma (γ) Cassiopeiae, the central star in the W, plays host to two exceptionally low surface brightness nebulae that shine by the bright star's reflected light. **IC 59** and **IC 63** are pockets of dust lying near Gamma in space, probably composed of particles about the size of those in cigarette smoke. Rather than shining by fluorescence like an emission nebula, these objects simply bounce light from Gamma toward our line of sight. They would be invisible if Gamma didn't lie so close — about 30 parsecs away.

Moving south from Gamma, aim your telescope toward Eta (η) Cassiopeiae, a 4th-magnitude double star. From there, head south 2° and you'll see a triangle of 7th-magnitude stars, two of which are doubles. Surrounding this triangle is the elusive emission nebula **NGC 281**, a low surface brightness object that's challenging in any telescope. A wide field of view, a dark night, and a nebular filter are essential for spotting this



Galaxy NGC 1023
Magnitude 9.5 Size 8.7′ by 3.3′



Galaxy NGC 278
Magnitude 10.9 Size 2.2′ by 2.1′

hazy cloud. Look for filaments of gray-green light measuring a total of 35′ by 30′ in extent.

Six degrees northwest of Eta lies Beta (β) Cassiopeiae, the western end of the W. Positioned about 2° east of this bright star is **IC 10**, a galaxy that belongs to our Local Group and barely shines through the obscuring disk of Milky Way stars, gas, and dust. Large telescopes are required to spot this galaxy. On an exceptional night an 8-incher will show IC 10 as a fuzzy smear some 2′ across. But to see a central condensation and the galaxy's full extent (5.1′ by 4.3′), you'll need a 16-inch or larger telescope.

Now center your scope back on Beta. Roughly 3° southwest of this star lies one of the richest open clusters in the sky, **NGC 7789**. This cluster is easy to locate because it is placed midway between the 4th- and 5th-magnitude stars Rho (ϱ) and Sigma (σ) Cassiopeiae. Some three hundred stars of magnitude 10.7 and fainter crowd a diameter of 16′ in this impressive cluster. Visible as a ghostly glow in binoculars, the group appears as a rich swarm of white points of light in telescopes.

The northwestern reaches of Cassiopeia play home to two strikingly unusual objects. **M52** (NGC 7654), a bright, rich open cluster, and **NGC 7635**, an odd emission nebula, lie within a degree of each other. M52 is a stunning collection of one hundred 8th-magnitude and fainter stars packed into a diameter of 13′, giving the group a total magnitude of 6.9. The most notable characteristic of M52 is its great range of star colors, from white and blue-white to burnt orange. NGC 7635 lies 1° southwest of M52 and is nicknamed the Bubble Nebula because of the wispy shell structure revealed in long-exposure photographs. This nebula is visible in a 6-inch telescope, although it is quite faint due to low surface brightness.

Back in Perseus, south of the Double Cluster, lies a line of bright deep-sky objects accessible in small telescopes. **M34** (NGC 1039) is a striking open cluster composed of sixty white stars in a diameter as large as the Full Moon. Perfect for binocular observers, this cluster should by viewed at low powers when telescopes are employed. Several degrees south of this cluster lie three galaxies aligned north-south. **NGC 1003**, the northernmost galaxy, is a magnitude-11.5 spiral measuring 5.4′ by 2.1′. Two degrees south lies **NGC 1023**, the finest galaxy in Perseus. This object glows at magnitude 9.5 and spans 8.7′ by 3.3′. It is an E7 elliptical galaxy viewed nearly edge-on to our line of sight. **NGC 1058** is a magnitude-11.5 spiral that appears almost exactly round in telescopes.

The most mysterious and challenging deep-sky object in Perseus is **NGC 1499**, popularly known as the California Nebula due to its distinctive shape. An enormous but extremely faint emission nebula, the California is visible only under the best conditions — on dark nights when the contrast between object and sky is at its best. You'll probably need a 10-inch or larger scope to see it, although some observers report spotting the nebula's brightest parts with telescopes as small as 4 inches in aperture.

To find the California Nebula, sweep slowly north of the 4th-magnitude star Xi (ξ) Persei, which illuminates the nebula. Use wide-field binoculars or an extremely wide-field, low-power eyepiece. If you observe on an exceptionally dark night, you may see bright parts of the nebula's light as wispy, filamentary bands of faint light. In some areas these bands of light appear linear; in other parts they are strongly curved. If you observe the California Nebula, make a sketch or at least take notes describing what you see. You'll be in a relatively small group of people who have "conquered the California."

Whether you watch the bright clusters or stalk the faint nebulae, the region of sky containing Perseus and Cassiopeia offers a grand selection of targets for your telescope. Use the observing opportunities you have this autumn to get out under the stars and challenge yourself to experiment with these objects. View them at low powers, at high powers, with nebular filters, and with averted vision. Challenge yourself to see details that have previously escaped you. The treasures of Perseus and Cassiopeia, crown of the winter Milky Way, offer not only interesting things to see but also a fresh opportunity to sharpen your observing abilities. □

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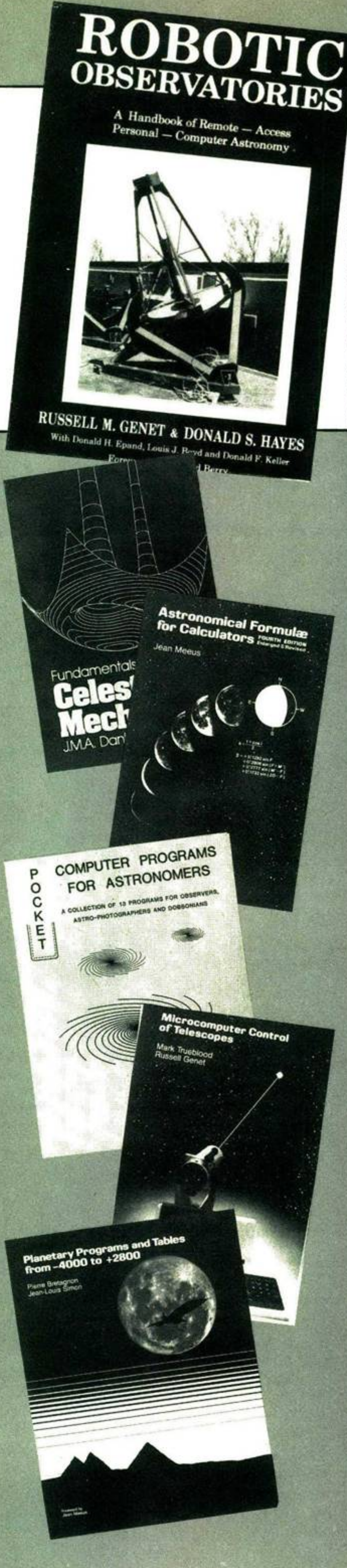
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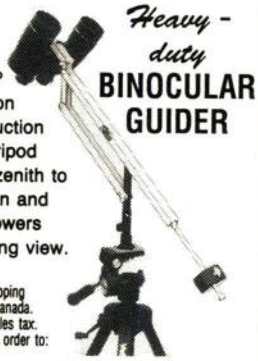

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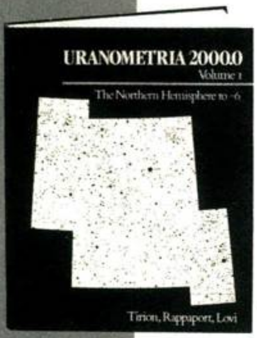
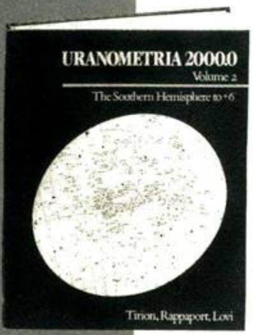




The Joy of Color Printing

It's not as difficult or expensive as you might think to get started in color printmaking, in fact it can be fun.

by Larry Myers

If you're like most astrophotographers, you're dissatisfied with commercial prints of your astronegatives. While the one-hour photo labs have their advantages (see "Great Astrophotos in Less Than an Hour" by Robert Bunge, August 1989), every astrophotographer knows that there's more detail in his or her negatives than commercial processing can reveal. Inevitably, this realization pushes you toward putting together a darkroom at home for custom color printmaking.

Many amateurs shy away from such a step, however, because it seems too complicated or expensive. Don't believe it! New processing kits have greatly reduced the expense and hassle of color processing. You sometimes hear it said that you have to know black-and-white photography before trying color. This is nonsense; I started out in color and have loved every minute of it.

Setting Up Your Darkroom

I bet you already have a darkroom. My first darkroom was the spare bathroom. Leaving the equipment set up caused problems, so I relocated to the laundry room. Duct tape and felt made a light-tight seal around the laundry room door.

The laundry soon became cramped though, so I moved into the garage, where I now have a darkroom in one corner, six feet on a side. Over the rafters I draped black plastic sheeting long enough to reach to the floor. This provides two "walls" and the garage provides the other two.

My darkroom has no running water, so I wash the prints in the kitchen sink. I have one table to hold the enlarger and use another for processing. This textbook "dry side-wet side" setup keeps negatives and chemicals safely separated.

I bought most of my equipment used for less than $300. The first piece of equipment to purchase is the enlarger. Before you buy one, visit a local photo supply dealer or browse through a magazine such as *Popular Photography*. Note the prices of new enlargers and look for a used one at about half the cost. If there is no source in your area for used photo equipment, try *Shutterbug* magazine (5211 S. Washington Avenue, Titusville, FL 32780); it lists dozens of used-equipment dealers.

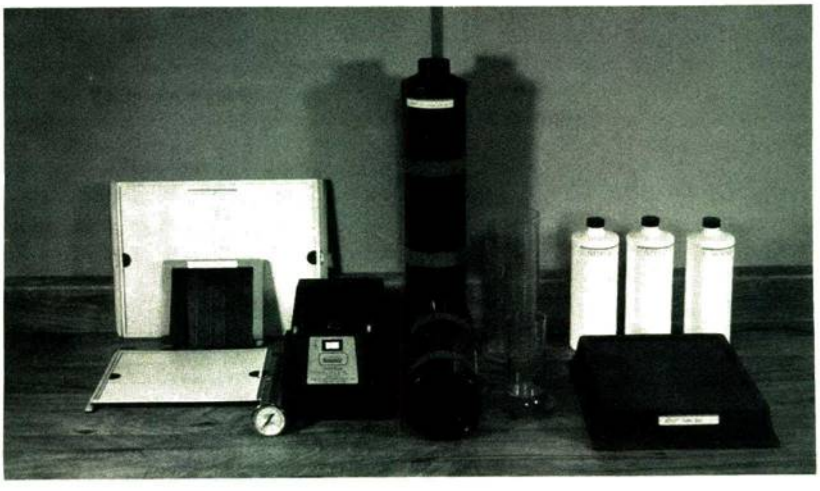
You don't need an enlarger with a color head; a black-and-white model works fine as long as it has a color filter drawer. It's best to choose a well-known brand such as Beseler, Omega, or Durst; I spent $200 on a Beseler 23C II with a lens and a negative carrier. Pick an enlarger with a sturdy stanchion, the stronger the better. Also, make sure the enlarger includes a negative carrier and a spare bulb.

Enlargers usually come with a lens; 50mm is good to start with. If the lens provided is of low quality, you'll get poor images, so consider upgrading it. Better brands include El-Nikkor, Rodenstock, and Leitz.

The lens will have an internal diaphragm, typically ranging from f/3.5 to f/16. The f/3.5 setting allows the greatest amount of light to pass through, f/16 allows the least. You "open" the aperture (turn it toward a lower number) for more illumination and "close it down" (turn toward higher numbers) for less. Get familiar with changing the f/stop in the dark.

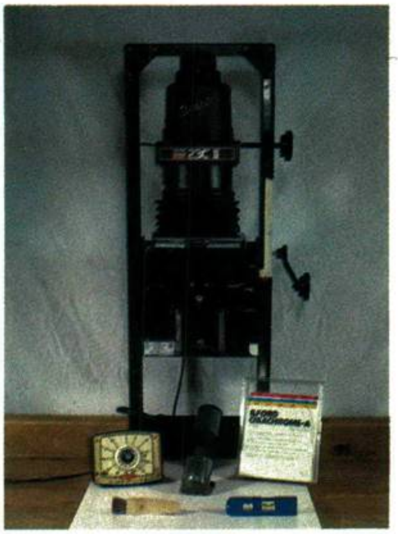
You will need a timer to control exposures. Timers are either mechanical or digital; I used an old mechanical one for years before buying a digital. They are available from Jobo, Time-O-Lite, Omega, and Graylab. Make sure the timer's switch can handle the wattage of the enlarger's bulb — most are clearly marked.

To get precisely focused prints, you need a grain magnifier, which is a



CHEAPER AND EASIER to use, the new color kits have encouraged many astrophotographers to try printmaking in a darkroom at home.

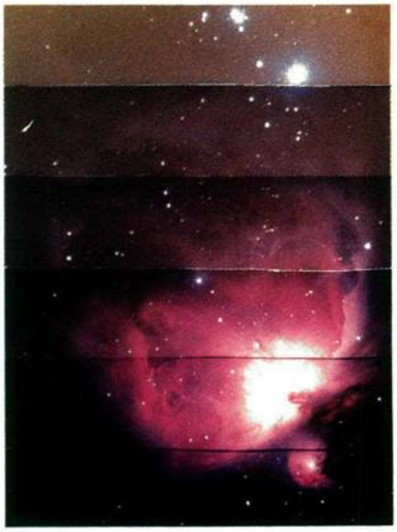
NO COMMERCIAL PROCESSING can unlock all the detail that lies in a good astro-negative, such as this one of the Lagoon Nebula in Sagittarius.



WITH GOOD USED EQUIPMENT available, there's no need to outfit the darkroom with new. Search local camera stores and the national photo magazines for bargains.

Beseler
ILFORD CIBACHROME-A

LOWER IN COST, black-and-white enlargers usually have a slot or drawer for inserting color filters. These are necessary if the enlarger lacks a color head.



TEST PRINTS ARE ESSENTIAL to produce high-quality finished work. A test print easel lets you make multiple trial exposures on the same piece of print paper.

kind of small microscope. The grain magnifier is designed to let you examine the negative in the carrier and adjust the enlarger's focus until it is as sharp as possible.

Prints are processed in light-tight roller drums, which come in many sizes; I use 8x10 and 11x14 drums most frequently. Although there is nothing wrong with rolling the drum on a level countertop during processing, a drum with a motor base gives more uniform agitation and more consistent results.

If you are working with a black-and-white enlarger, a set of color printing filters is necessary. A set (Kodak or Ilford) normally consists of incremented filters — six each of yellow, magenta, and cyan, plus an ultraviolet filter. The size of the filter needed depends on the size of the enlarger's filter drawer.

To hold print paper flat and in position on the enlarger's baseboard, you need an easel. Common sizes range from 5x8 to 16x20 or larger; I use 8x10 and 11x14 most often. Along with a normal printing easel, buy or build a test print easel. This device has flaps to allow multiple exposures on the same sheet of paper.

You may opt for processing at temperatures warmer than ambient; this will require a warm temperature bath. An aquarium with a heater provides good temperature control for the solutions, but you have to cover any lights built into the heater. I keep individual 1-liter plastic bottles of processing solutions in the aquarium until I need them.

A camel's hair brush or a can of dry air will clean dust off negatives. A 250-milliliter graduated cylinder (or "graduate") is necessary for measuring chemicals. A light-tight paper safe can store unused paper during a printing session. Finally, get a good darkroom thermometer.

Laying in Supplies

Processing kits by Kodak, Beseler, and Ilford are available in sizes from 1 liter and up. Kits normally have several steps. Although the three brands mentioned all produce excellent results, the Beseler two-step kit is the easiest to start with.

How large a kit should you buy? With practice, about a dozen 8x10 prints can be processed with a 1-liter kit, depending on the drum. After you become experienced, you can expect to process four to six 8x10 prints per hour. Mixed Beseler chemicals stay fresh about six weeks if they are kept tightly capped in a cool place.

Prior to printing, decide the processing temperature using the instruction sheet. Then mix the chemicals according to the instructions and stabilize them at the desired temperature in the aquarium.

You hear horror stories about controlling the temperature of the processing solutions. While it's true that constant temperatures are required, a variance of plus or minus 3° F has made no noticeable difference in my astrophotographic prints. With the color printing kits available today, temperature control just isn't the hassle it used to be. Kits even allow for room-temperature processing, eliminating the need for a warm "bath." (On the other hand, the cooler the processing temperature, the longer processing takes.)

There's a variety of print papers to choose from. I mainly use Kodak Ektacolor Plus-F for its glossy surface and high contrast. Try a few different types and decide for yourself. As with chemicals, larger quantities are less expensive on a per-print basis. I buy paper in 100-sheet boxes for about $35. Store the paper box in the refrigerator and to avoid condensation remove it an hour before use, but remember to leave the paper sealed in the package until it has warmed up.

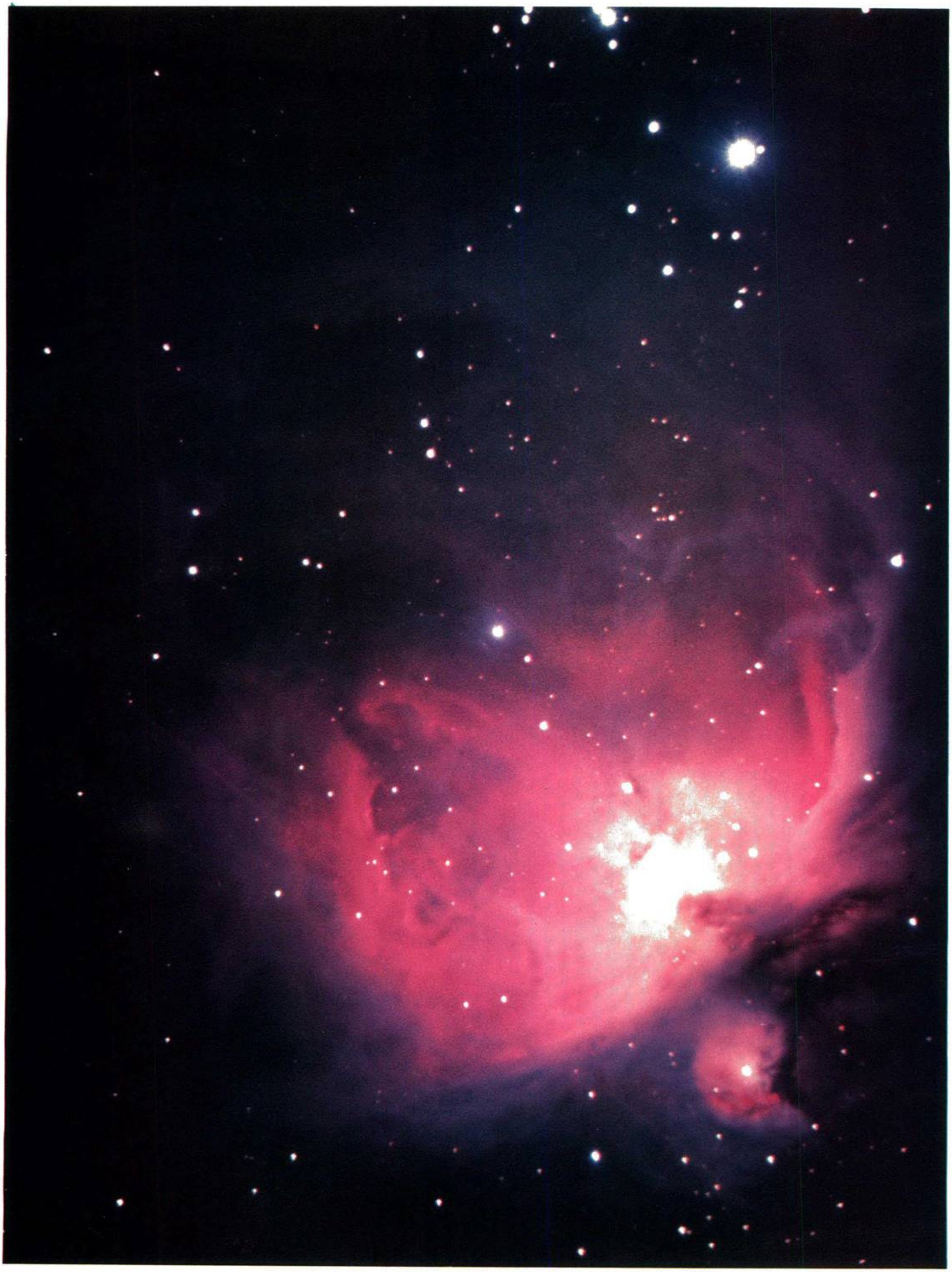
Now do some last-minute checking. Is the darkroom truly light-tight? (Let your eyes dark adapt and look for light leaks.) Are processing solutions going to splash on the negatives? Is your equipment arranged logically? How about a container to dispose of used chemicals? (I use a 5-gallon bucket.) Are you maintaining the chemicals at a constant temperature? Have you thoroughly read and understood all the instructions?

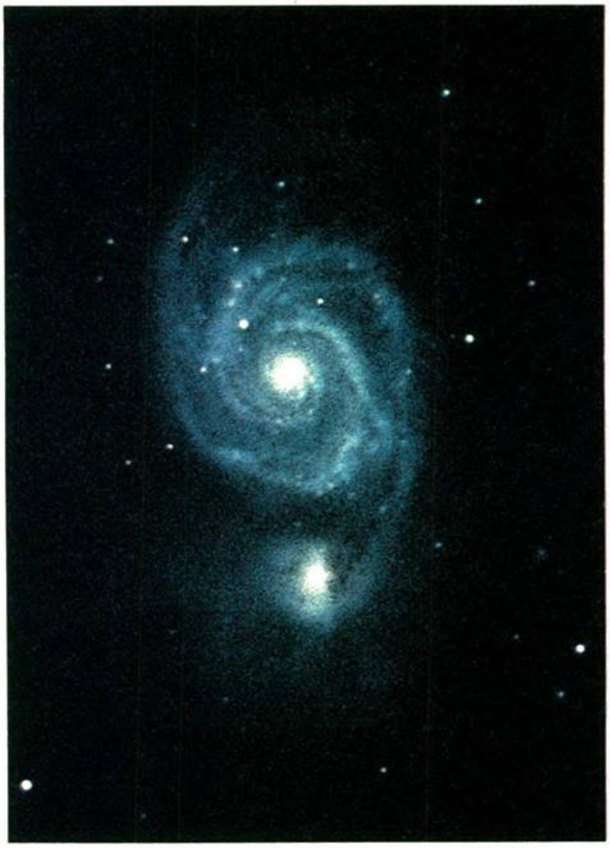
Making Your First Prints

Now that you have all your supplies and equipment in order, you're ready to begin printing. I'll take you through the process step by step.

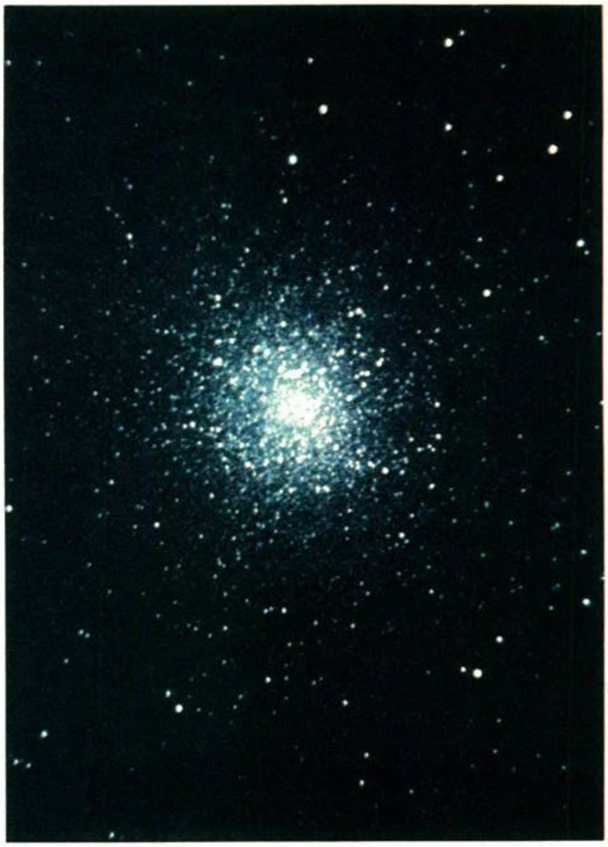
You should begin with a test print. This is an 8x10 with a graduated series of exposures in strips (see photo top right). A test print is like making five or six trial prints in one. To make

BEAUTIFUL AND CHALLENGING, the Orion Nebula will make great demands on your printmaking skills. Few other objects provide such gratifying rewards.

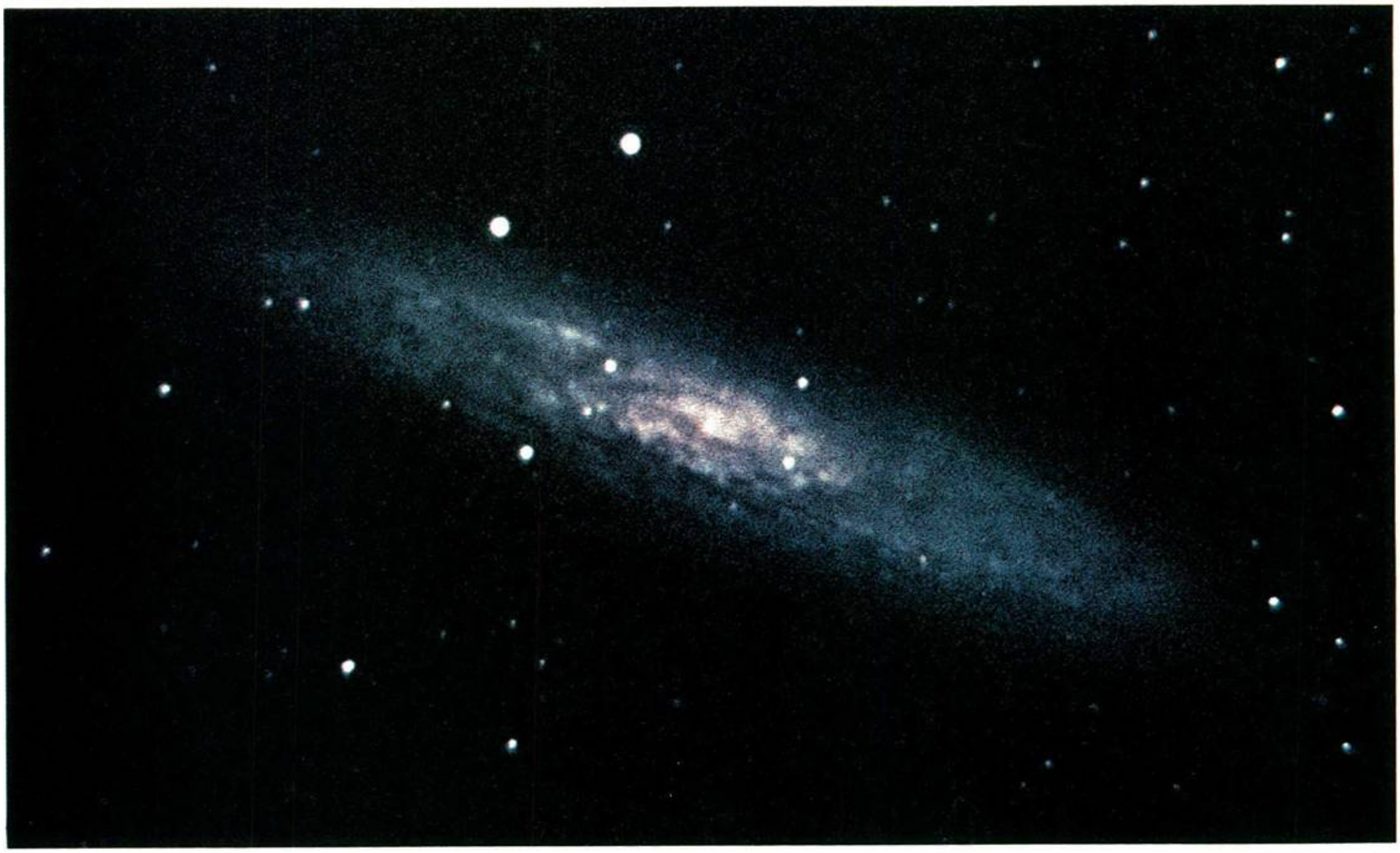




DELICATE SPIRAL ARMS in the Whirlpool Galaxy (M51) call for a lightly exposed print.



CHAINS AND SPECKLES OF STARS in the globular cluster M13 demand a heavier exposure.



CURDLED WITH CLOUDS OF DUST and gas, galaxy NGC 253 in Sculptor requires a carefully adjusted color balance and just the right exposure to yield a print with greatest impact.

Color Filter Guide

If the print . . .	add . . .	or subtract . . .
needs blue	yellow	cyan & magenta
needs green	magenta	yellow & cyan
needs red	cyan	yellow & magenta
is too blue	magenta & cyan	yellow
is too green	yellow & cyan	magenta
is too red	yellow & magenta	cyan
is too yellow	yellow	magenta & cyan
is too magenta	magenta	yellow & cyan
is too cyan	cyan	yellow & magenta

a test print, select a negative of a bright object that you know will print well. Brush off any dust, put it into the negative carrier emulsion side (dull side) down, and place the carrier in the enlarger. Turn the darkroom lights off and turn on the enlarger. Open the lens aperture fully.

Adjust the head height so that the projected image just covers the test easel. Place the grain magnifier on the easel and adjust the enlarger's focuser so that the grain is as sharp as it gets. Turn off the enlarger and turn on the darkroom lights.

At this point you must decide which filters to use. Paper manufacturers list a starting filter combination on the package because each batch differs just a bit. For example, the label might read 20Y, 25M, 0C. These instructions translate to a filter combination of 20 yellow, 25 magenta, and 0 cyan. Insert a 20 yellow filter, a 20 magenta filter, plus a 5 magenta filter into the filter drawer. If the kit has an ultraviolet filter, put it in too.

Use the least number of filters you can to make a combination: use one 20 filter, not two 10s. At any one time use a combination of two or less colors. If you use all three (yellow, magenta, and cyan) at once, you get a neutral tone and an increase in density that extends the exposure time.

Set the enlarger's timer to 20 seconds (an arbitrary choice). By the way, if the print comes out overexposed (too dark) or underexposed (too light), adjust the *aperture*, not the time. If you alter the time, the filter pack may have to be changed. Once you get a print you like, stay with that time setting.

Now recheck that the aperture is wide open. Turn out the darkroom lights and remove a fresh sheet of print paper from the package. Place the paper under the test easel's strips. Open just the left strip and make an exposure. Close that strip, open the next one, close the aperture one stop, and repeat the exposure. Continue the procedure, decreasing the aperture each time, until you've made as many exposures on the sheet as the test easel allows. Remove the paper and place it into the processing drum. With the drum cap tightly in place, turn on the darkroom lights.

Although the directions don't always call for a "pre-wet" (a tap water rinse prior to step 1), it's good to do because a pre-wet swells the paper and helps the chemicals start to work evenly over the print.

For an 8x10 I normally begin with about 100 milliliters of tap water at the right temperature. I agitate the pre-wet for about 30 seconds. While agitating, I remove the next solution from the bath and pour it into the graduate. Doing this with each solution helps the process go smoothly. If you are using a warm bath, expect the solutions to cool a degree or two during pouring and processing and plan your times accordingly.

After the pre-wet, follow the instructions, making sure to drain the drum thoroughly between each step. The directions call for a final wash at the same temperature as the processing, but I don't always manage this. After washing, lay the print out face up on paper towels and carefully squeegee off the excess water. At this point, I use a hair dryer set at low heat to speed the drying.

Do not evaluate a wet print — let it dry first. The color changes as it dries and a wet print tells you very little.

Getting the Print Just Right

After the test print is dry, it's time to evaluate it. Can you see an image? The darkest strip is from the first exposure you made; the more light the print gets, the darker it becomes. As you closed down the lens aperture, the strips should have become lighter. You may get one strip that looks just right, but most likely adjustments will be necessary. If all the strips are too light or too dark, you'll need to increase or decrease the exposure time as necessary and repeat the entire test print procedure.

You may see one strip that's too dark while the strip next to it is too light. For example, the f/5.6 strip is too dark and the f/8 one is too light. Try the next exposure at the mid-point between f/5.6 and f/8. This will probably get you closer to an ideal exposure.

Color adjustments are trickier. The table on this page gives some guidelines for corrections. I usually make filter adjustments in steps of 10 to 20. For example, if a print requires more blue and the original test print was shot with a combination of 20 yellow, 25 magenta, and 0 cyan, I might increase the yellow filter to 30 or 40 and leave the magenta and cyan alone. Note that the chart says that if you "need blue" you should add yellow or subtract cyan and magenta. Because we printed with a combination of only two colors (yellow and magenta), there is no cyan to subtract.

It will probably take you some time — maybe even two sessions — to get your first good print. You may become very frustrated but don't give up. There's no real shortcut to learning printing and eventually you'll reach a point where everything clicks. You'll find that once you reach an aperture setting and filter pack that works, they will probably hold true for most of that particular roll of film.

Keep a notebook or logbook in the darkroom. Work slowly and record *everything* — settings, filters, negative roll, and frame number — that you do. An orderly notebook is invaluable; I always record what I'm going to do before I do it and protect my notebook as I protect my negatives.

Jack Newton once said that darkroom work is 60 percent of astrophotography ("How to Make Great Astrophotos," November 1988). He was dead right. It does take time, but it's worth it because it's the only way to get the most from your negatives.

There are so many print enhancement techniques that it would take an entire issue to list them all. Many of the methods can be found in back issues of ASTRONOMY. You'll find that articles you once skimmed over suddenly become sources of information and technique.

The best way to learn to make prints is by doing it. Get in there, don't fret about the mistakes, and you'll be making fine astro-prints in less time than you can believe. □

Larry Myers is a California astrophotographer; his last article, "Working against the Grain of Fast Films," appeared in the February 1989 issue.

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SUPERNOVA HUNTER

Australian Robert Evans talks about how he became the world's most prolific discoverer of exploding stars.

by Robert Evans, as told to Robert Reeves

Twenty or thirty times per year, a star explodes in a distant galaxy, emitting a burst of light that is visible from Earth for days or weeks. By studying the nature of these exploding stars, called supernovae, astronomers glean information about the way in which massive stars die and the processes that govern their lives.

Most supernovae are very faint when discovered. Therefore, astronomers at observatories with large telescopes and automatic search programs discover most supernovae, especially the faint ones. However, professional supernova hunters have competition, evidenced by the standard reaction when astronomers suspect that they have found a supernova: "Let's confirm it before Evans gets it."

Beginning with his first find in 1981, Reverend Robert O. Evans, an amateur astronomer living in Hazelbrook, New South Wales, Australia, has discovered eighteen supernovae with 10-inch and 16-inch telescopes. Evans' count far surpasses that of any other person. How does he do it? What attracted Evans to searching for supernovae? This article resulted from an interview of Evans conducted by amateur astronomer Robert Reeves of San Antonio, Texas.

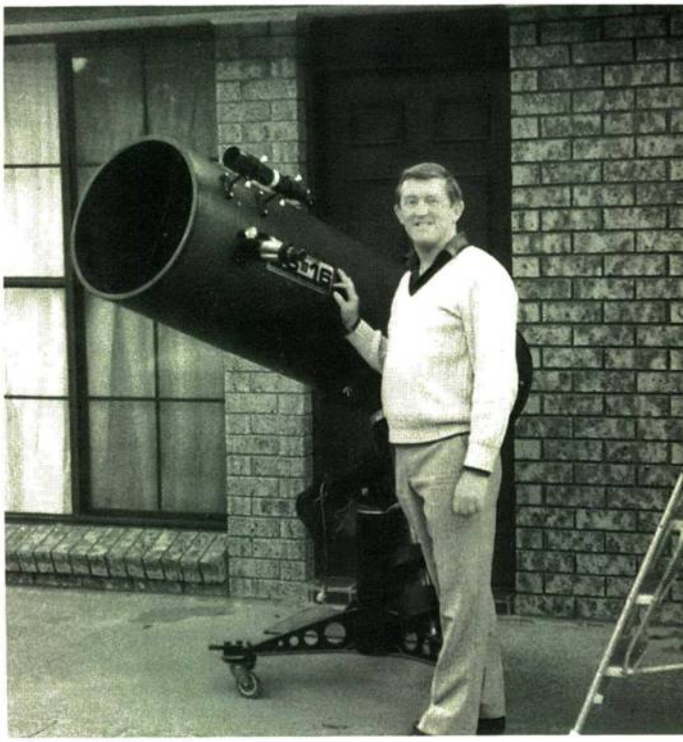
I didn't start off hunting for supernovae. I began observing the sky when I was ten years old. I had an old star atlas and a little book on the constellations, and I would take them outside and look up at the stars with no optical aid. On rare occasions I could borrow a small pair of binoculars. After doing this for some time, I learned the main star patterns and the locations of a few bright deep-sky objects.

A few years later, after my brother became an optometrist, he helped me make a refractor using a spectacle lens and a microscope eyepiece, along with rolls of paper and a cardboard tube. The mounting was very crude, but using this telescope expanded my interests and I began to make frequent observations of planets and open star clusters.

Around my eighteenth birthday, I bought a proper 2-inch refractor and an old 5.5-inch reflector that consisted of only a tube assembly. I had no guidance about how to make the reflector work properly, so mirror alignment eluded me for a year or more. But in due course, I learned how to sit cross-legged on the flat roof of the laundry next door and prop the tube against my knee, scanning for open and globular clusters (without being able to resolve any of the globulars into stars). After going through this phase of looking at clusters, I gradually began to look at galaxies.

At this point, by chance, I obtained a few publications mentioning supernovae. I was enchanted by these exploding stars and began to look at galaxies, hoping I might spot an undiscovered supernova. At that point I was twenty-one years old, the year was 1958, and my constant companion was an old copy of *Norton's Star Atlas*. Occasionally I traveled to Sydney Observatory and recorded positions of galaxies from the Shapley-Ames catalog.

Then, just as I was on my way, life came around and interrupted my astronomical pursuits. For ten years I was either studying at the university or living in urban loca-



ACE SUPERNOVA HUNTER Robert Evans poses with his telescope in New South Wales. Evans' latest find was a supernova in M66 (upper right), which he discovered using Gregg Thompson's detailed charts (right).

Sky Atlas 2000.0

Scale: 1

NGC 1672

Mag. 11·5

Sky Atlas 2000.0

Scale: 10″ = 1mm.

N.G.C. 3166

Mag. 11·5

Dim. 3′·9 × 2′·1

R.A. (1950) 10
(2000) 10

Sky Atlas 2000.0

Scale: 10″ = 1mm.

N.G.C. 381

R.A. (1950) 11 38·4
(2000) 11 41·0 DEC. + 1
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tions, both of which made observing galaxies impracticable. But I never lost the desire to look at galaxies, and I developed a burning desire to get a larger telescope that would enable me to see fainter galaxies — someday, when I had a good sky again. I wanted a 12-inch scope, but such an instrument was almost nonexistent in all of Australia at this time. Finally, in 1969, my job took me away from Sydney and I regained the freedom to look at the stars. I was in business for hunting supernovae once again.

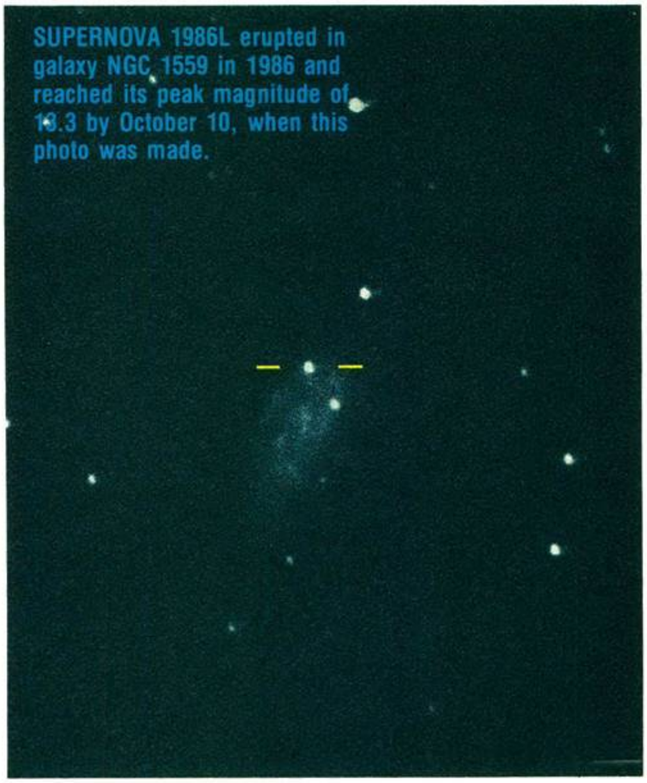
I acquired a 10-inch f/4.3 mirror in 1960 and by 1970 had the telescope and the dark sky needed to begin a systematic observing program. At this time a 10-inch telescope was an extremely large one, especially in Australia. I ran into problems immediately. I discovered that almost no photographs were available that could be used as suitable comparison charts if I found a star I suspected was a supernova. Each time I came across a faint star I hadn't noticed before, there was a need to check it against a photograph. So I became a nuisance to a number of professional astronomers in several countries, asking them to help me out by checking suspected stars. After a year of this, however, I decided that if the search was to continue I needed some better way of checking possible supernovae for myself.

It was not until 1979, when I heard about Gus Johnson's discovery of a bright supernova in M100, that my interest was rekindled. Johnson, an amateur astronomer in Maryland, found his supernova (1979C) with an 8-inch reflector. The very thought of this discovery prompted me to try to overcome all of my problems and surge ahead.

I first sought the advice of the nearest astronomy club, which was located in Brisbane, Queensland. They told me about two other Australians active in studying supernovae: Gregg Thompson, who was preparing comparison charts for 230 galaxies, and Tom Cragg of the Anglo-Australian Observatory, who agreed to check out all of my suspected supernovae. Cragg helped me make many copies of photos of galaxies from the survey plates at the Anglo-Australian Observatory. At last I had the proper materials to search for supernovae.

As a result, I made two supernova discoveries (in the galaxies NGC 1532 and NGC 1316) some fifteen days apart early in 1981. By the end of 1985, I had made eleven discoveries with the old 10-inch telescope. I now use a Meade DS-16 telescope, provided by CSIRO, Australia's governmental research organization. By February 1989, I brought the total number of discoveries to eighteen, including the bright supernovae in NGC 5128 (1986G), M58 (1988A), and M66 (1989B). Of the discoveries made since 1985, six were made with the DS-16 and one with the 10-inch scope.

One of the main scientific advances my supernova discoveries helped to bring about was the recognition of a new class of supernovae called Type Ib. Since the first *in-depth studies* of supernovae around 1940, two main classes were recognized: Type I supernovae, events showing no hydrogen in their spectra; and Type II supernovae, events that do show hydrogen in their spectra. A few supernovae with peculiar spectra had been observed by the Italian astronomer Francesco Bertola in 1962 and 1964, but few astronomers paid attention to them. The supernova I discovered in M83 in 1983 (1983N) was quite bright and turned out to be an object with a peculiar spectrum. This star and another object I found a year later in NGC 991 (1984L) became the prototypes of the class of supernovae designated Ib.


SUPERNOVA 1986L erupted in galaxy NGC 1559 in 1986 and reached its peak magnitude of 13.3 by October 10, when this photo was made.

Type Ib supernovae are thought by some astronomers to be stars that start out with a mass between eight and twenty-five times that of the Sun. As they undergo thermonuclear reactions, these stars lose most of the hydrogen in their outer layers, resulting in a layered shell with helium on the surface. When these stars collapse and become supernovae, they have characteristically weak hydrogen lines.

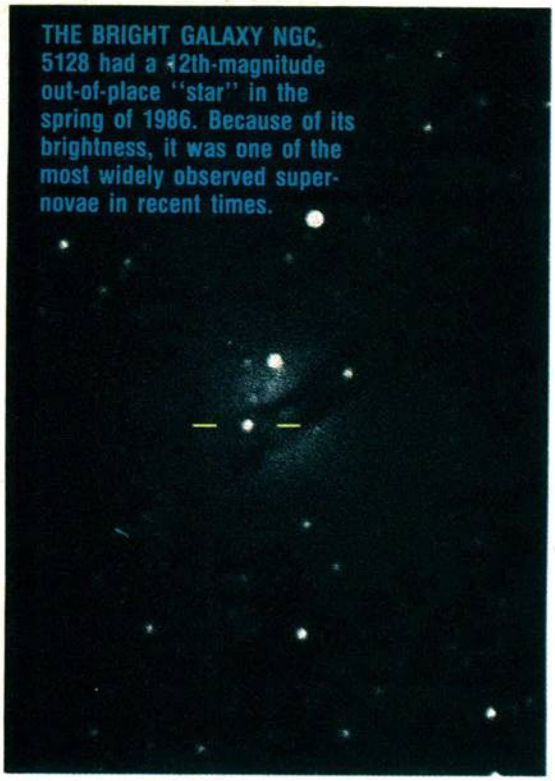
People often are surprised when I tell them I observe from my home in Hazelbrook, New South Wales. The DS-16 lives in the garage and has wheels so I can simply roll it out into the yard. There is a street light outside the front fence, and I have to either ignore it or hide from it behind trees and bushes in the front garden.

I typically observe with two parfocal Plossl eyepieces. I locate the galaxy I want to view in the finder scope and insert the low-power eyepiece (70x) to center the galaxy in the field of view. Then I switch to the high-power eyepiece (200x) to examine the galaxy and see if I can recognize any "intruding stars" in the field.

Despite the fact that I live fifty miles from Sydney, a city of 3.5 million inhabitants, the sky above Hazelbrook is reasonably dark, but it's not black. Unfortunately, this area of Australia experiences a great deal of cloudy weather. The average percentage of clear nights is only about 30 percent, with the fewest good nights in the summertime.

The amount of time I devote to supernova searching varies from month to month, depending on how many clear nights there are and which constellations are visible. Normally, I spend from fifteen to twenty-five hours per month at the telescope. Clearly, being able to walk out into the yard and observe is critically important: if I lived in the city and could observe only a few times per month, my search program would be very difficult to carry out.

I've found that the most important factor in the program is to observe as many galaxies as possible on a



THE BRIGHT GALAXY NGC 5128 had a 12th-magnitude out-of-place "star" in the spring of 1986. Because of its brightness, it was one of the most widely observed supernovae in recent times.

Supernovae Discovered by Robert Evans

Object	Galaxy	Discovery Date	Maximum Magnitude
SN 1981A	NGC 1532	Feb. 24, 1981	13.0
SN 1981D	NGC 1316	Mar. 9, 1981	12.7
SN 1983G*	NGC 4753	Apr. 6, 1983	12.8
SN 1983N	M83	July 3, 1983	11.5
SN 1983S	NGC 1448	Oct. 6, 1983	14.5
SN 1983V	NGC 1365	Nov. 25, 1983	13.5
SN 1984E*	NGC 3169	Mar. 29, 1984	14.0
SN 1984J	NGC 1559	July 27, 1984	12.9
SN 1984L	NGC 991	Aug. 28, 1984	13.8
SN 1984N	NGC 7184	July 20, 1984	14.0
SN 1985P	NGC 1433	Oct. 10, 1985	13.5
SN 1986A	NGC 3367	Feb. 4, 1986	14.0
SN 1986G	NGC 5128	May 3, 1986	11.5
SN 1986L	NGC 1559	Oct. 7, 1986	13.3
SN 1987B	NGC 5850	Feb. 27, 1987	14.4
SN 1987N	NGC 7606	Dec. 14, 1987	13.7
SN 1988A*	M58	Jan. 18, 1988	13.5
SN 1989B	M66	Jan. 30, 1989	12.0

* Codiscovery. SN 1983G with Kiyomi Okazaki; SN 1984E with Nataliya Metlova and Kiyomi Okazaki; SN 1988A with Kaoru Ikeya.

regular basis. I have about 1,500 target galaxies on my observing list; each month I observe 500 to 1,000 of them.

The second most important factor is observing regularly. I observe every night I can, and I check as many galaxies as possible each month. Galaxies that are relatively close, and therefore might produce bright supernovae, get checked several times per month. The reason for frequently checking these galaxies is to catch a supernova while it is still rising in brightness, because these finds have the greatest value for astronomers studying supernovae. It's also important to check galaxies soon after Full Moon to catch any supernovae that might have occurred while few people were observing. Also, it's important to keep a logbook with all of your observing notes for future reference.

When observing galaxies, take a brief but careful look and keep moving on. My typical pace is between 30 and 100 galaxies per hour. My record for checking galaxy fields is 570 in one night back in March 1984. That averages to one galaxy per minute throughout a ten-hour night. On a similar night two years later, I logged 454 galaxies in seven-and-a-half hours. On another night I checked 337 galaxies in four hours and found a supernova in the 338th galaxy. Once you have charts and get used to checking field stars — and you come to *know* the fields — you can search for supernovae at a breakneck pace. It's unlikely that you'll find a supernova if you watch only a handful of galaxies.

I do not have a photographic memory, as some of my friends like to think. Repeatedly observing these galaxies has taught me to find them quickly. I can also normally remember the typical appearance of most of the galaxies under different atmospheric conditions. This is important for checking large numbers of galaxies because it cuts down on the time required to check charts and photographs.

Many people I've recently spoken with wonder where supernova searching is headed. Relatively few amateur astronomers are looking for supernovae visually. A few are searching photographically, and there seems to be a rising interest among dedicated observers. Steve Lucas of Midlothian, Illinois, publishes a newsletter called *Sunsearch*, which is specifically targeted at amateurs interested in supernova hunting. Of course, professionals are deeply involved with supernova discoveries; they make their finds by photography or with automated telescopes designed for photographing and comparing galaxy fields. A team from Berkeley, for example, employs an automatic search camera that has had some success.

This is mildly alarming to some amateurs who are just getting interested in supernova hunting. However, automatic cameras will not put amateur astronomers out of business. There is room for everybody because there are so many galaxies to be monitored. Amateur and professional astronomers can work together as a team, covering all the bases and leaving no galaxy unchecked. We are still a long way from that point: the supernova I found in M66 in early 1989 proves that amateurs can find a bright supernova in a bright galaxy that was under observation by professionals.

It gives me a marvelous feeling to discover a supernova, especially if I can catch one early and help professional astronomers follow it as it brightens and dims. However, there are supernova droughts. Sometimes a year or more can pass with no supernovae appearing in the galaxies I watch. When this happens, I increase the number of galaxies I am monitoring and keep at it. The barren periods don't last forever, and it doesn't help to get discouraged.

The most important thing to keep in mind is that amateur astronomy is a hobby. Supernova searching is a relaxing, enjoyable way to observe the sky that can pay off in big ways for the advance of science. It's also an area that is relatively simple: it doesn't require computerized mountings, CCDs, or super-duper video cameras. With the combination of a telescope, charts, persistence, and a love of the sky, you can discover your very own supernova — maybe as soon as next week. ☐

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WANTED – Correspondence with amateur astonomers. Contact Armand Rivera, A.A. 40058, Bogota, Columbia.

WANTED – Form 4 high school student in Zimbabwe would like guidance and assistance for his examinations in astronomy. Needs question papers from the past three years and any other materials. Contact Daishik Chauhan, 5 Plumer Street, North End, Bulawayo Zimbabwe.

PHOTOGRAPHING DETAILS ON JUPITER

Amateur astronomers are now producing some of the finest Earth-based photos of Jupiter, according to John H. Rogers, director of the British Astronomical Association's Jupiter Section. Rogers is analyzing results from a group of observers who are recording features on Jupiter using tricolor photography, high-grade black-and-white photography, and CCD imaging.

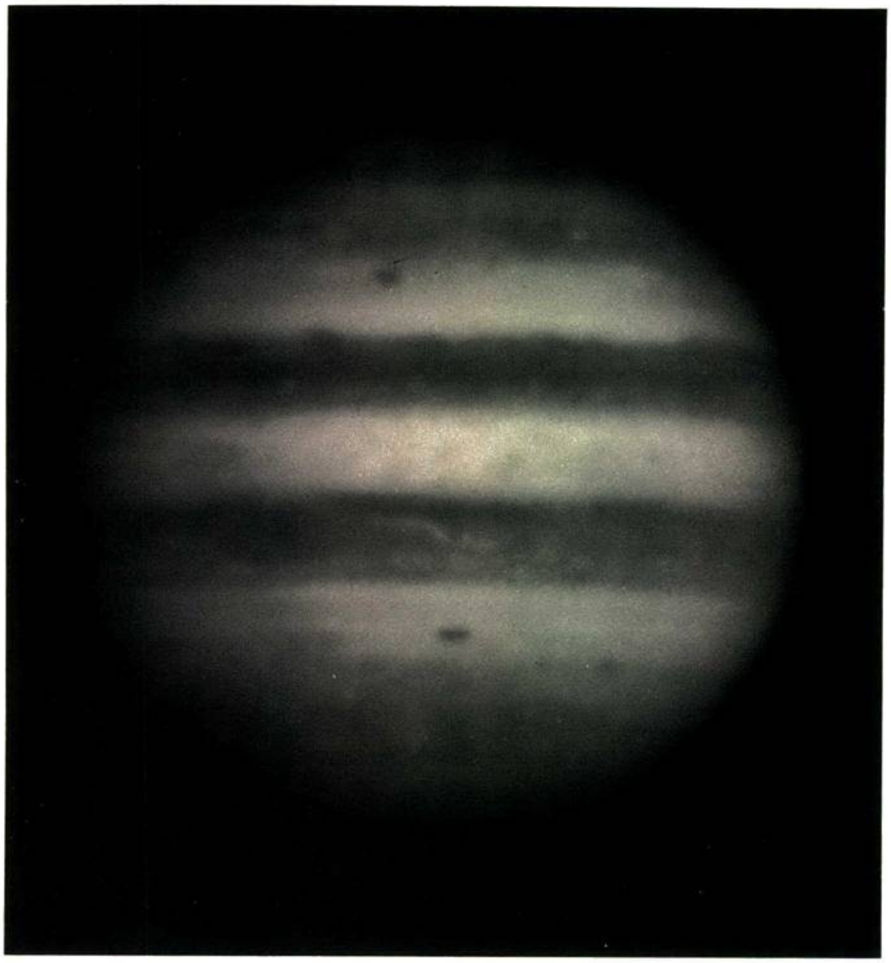
Jean Dragesco, a talented amateur astronomer in France, used the 1.06-meter reflector at the Pic du Midi Observatory in the French Pyrenees. In 1986 he took photos of Jupiter in deep red light (with a Wratten 29 filter), white light, deep blue light (Wratten 49 filter), as well as direct color photos. Because of atmospheric dispersion and film characteristics, the highest resolution images were the red and blue frames. Dragesco collected a series of negatives made at nearly the same time, and Rogers recently combined them into a single color image that retains the resolution of the originals.

"Combining the monochromatic images was a tricky process," Rogers said. "Each set of three monochromatic images was rephotographed onto a single frame of Ektachrome 100 color transparency film: the red print through a Wratten 29 filter, the white light print through an Ilford 625 green filter, and the blue print through an Ilford 622 blue filter. Exposures were adjusted to achieve the best overall color balance.

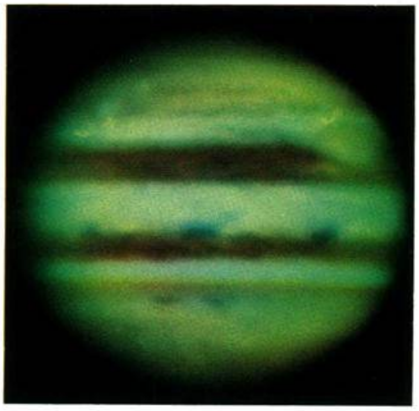
"Although they exaggerate contrast and don't yield true colors," said Rogers, "they show more detail than 'straight' color photos and show distinct color contrasts. Some of the features recorded by Dragesco are the Great Red Spot, a 'little red spot' in the same latitude, a small white oval in the South Temperate Belt, and dark bluish patches along the southern edge of the North Equatorial Belt. On the northern edge of the North Temperate Belt, the dark streaks show a broad range of tints.

"In contrast to Dragesco's photographs," explained Rogers, "black-and-white shots by Isao Miyazaki and Terry Platt show how the planet has changed over the past two years. The images for Dragesco's color composites were made in 1986, and Miyazaki and Platt's photographs were taken in late 1988. Miyazaki's photographs represent conventional Jupiter photography at its best, while Platt's show the result of applying CCD video technology to imaging Jupiter.

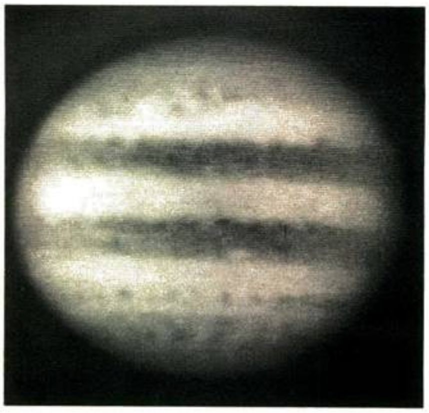
"Several differences between the



JETSTREAMS IN JOVIAN BELTS show clearly in Isao Miyazaki's image of Jupiter made on September 11, 1988. Miyazaki used a 16-inch f/6 reflector, Tech Pan film, and a 3-second exposure.

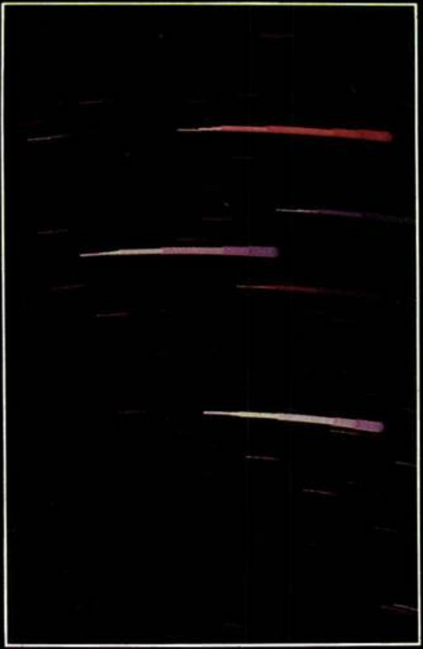


FINE JOVIAN DETAILS are visible in this color composite photo made on July 20, 1986. Jean Dragesco combined three black-and-white negatives made with a 1-meter telescope at Pic du Midi Observatory in France.



DOTTED WITH OVAL CLOUDS, Jupiter's dark belts and light polar regions appear markedly different in this photo from December 12, 1988. Terry Platt used a 12.5-inch refractor to record the Jovian disk onto a CCD.

APRIL'S MOON-PLEIADES CONJUNCTION

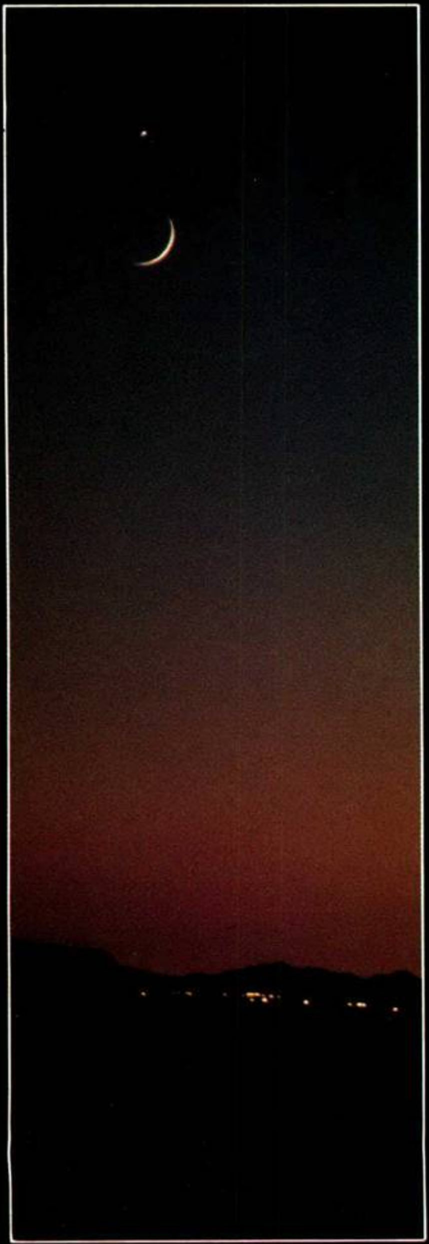


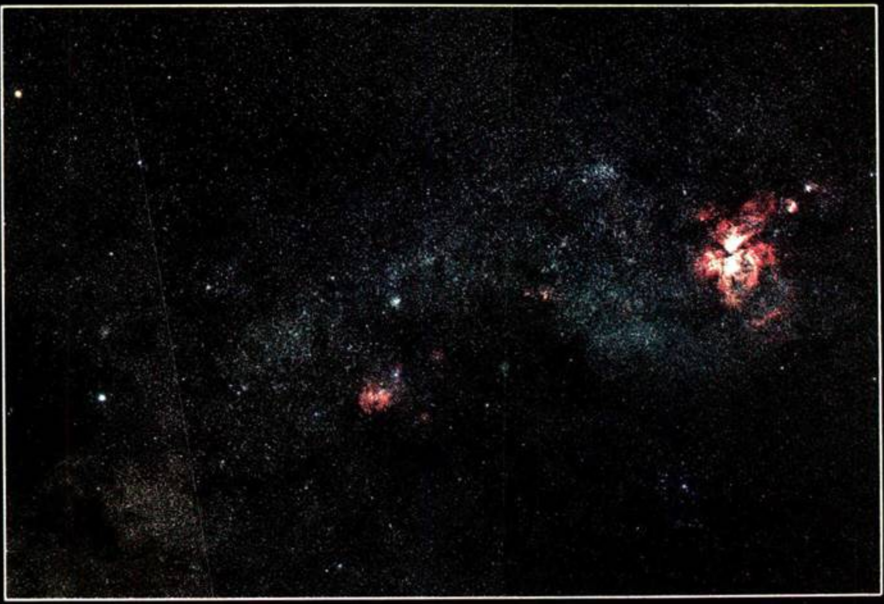
The Moon passed through the Pleiades star cluster in Taurus on April 9, 1989, occulting some of the cluster's stars and forming a striking celestial sight. George R. Viscone's photograph of the two objects nets this month's $100 "Best Astrophoto" award. An avid observer from Clifton Park, New York, Viscone used a 3-inch telescope, Fujichrome 100 film, and an 11-second exposure.

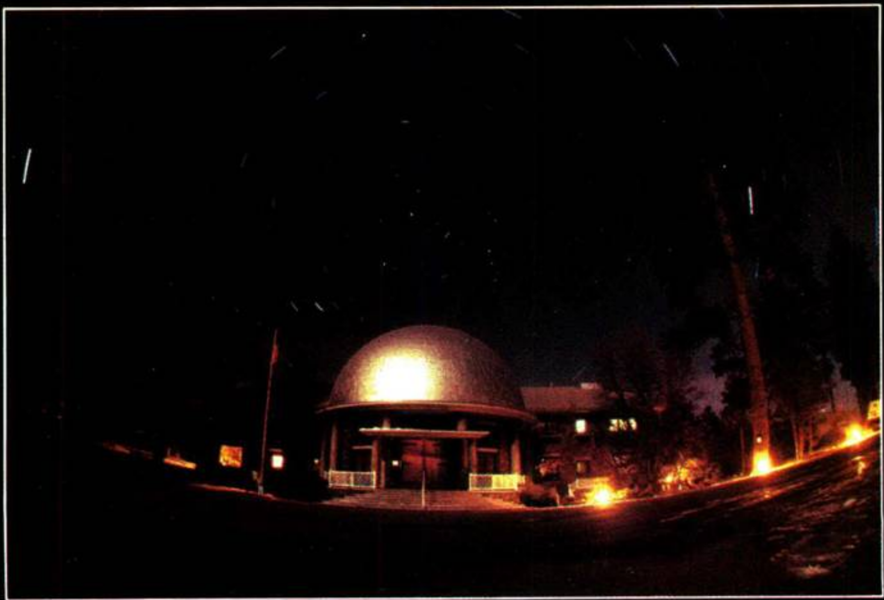
On July 4, Patrick Wiggins of Salt Lake City, Utah, captured a conjunction of the Moon and Venus on film (bottom left). Wiggins used a 200mm f/3.5 lens, Ektachrome 200 film, and a 1/4-second exposure.

Ronald Royer used a tricolor technique to make this photomosaic of the region of Eta Carinae (below). On a trip to the Southern Hemisphere, Royer used a 4-inch f/5 lens to photograph the same area of sky on black-and-white film in three different colors of light. Royer combined the photos in his darkroom using filtration to produce the color version reproduced here.

On a trip through Flagstaff, Arizona, Geoffrey Chester of the Smithsonian's National Air and Space Museum photographed star trails over Lowell Observatory (bottom). Chester used a 16mm f/4 fisheye lens, Ektachrome 200 film, and a 20-minute exposure. In a very different star trail shot, Jim Barclay photographed Crux over Manly, Queensland, Australia (left). Barclay defocused the camera at five-minute intervals, creating a vivid record of star colors.







photos are visible," said Rogers. "The North Equatorial Belt clearly was much broader in 1988 than in 1986, when it extended far to the north and showed great turbulence. Both the North and South Temperate Belts have faded almost to invisibility and are apparently covered by white clouds. In the north, the dark streaks on the northern edge of the North Temperate Belt were the last parts to disappear. In the south, dark blocks remained, flanking two of the long-lived white ovals.

"The most curious change our Jovian photography has shown us," said Rogers, "is the proliferation of rapidly changing dark spots on the southern edges of the South Equatorial Belt and the North Temperate Belt. Those spots are blowing along in the jet streams that dominate these latitudes. Few such spots are visible in 1986, but many can be seen in Platt's photograph. We were delighted when we discovered that this outbreak of dark spots was the largest recorded since 1979, when *Voyager* imaged a similar flurry of spots. It reinforces the notion that amateur astronomers can indeed contribute to astronomers' photographic record of activity on nearby planets."

FOLLOWING COMET BRORSEN-METCALF

After many unsuccessful attempts to recover the periodic Comet Brorsen-Metcalf (1989o), on July 4, 1989, astronomer Eleanor Helin photographed the fuzzy spot at Palomar Observatory. At its discovery Brorsen-Metcalf was a 12th-magnitude object. However, by July 8 the comet brightened to magnitude 9.6 and had a coma measuring 9′ across, according to California observer Charles Morris. Moving in a fast arc across Pisces, Triangulum, Perseus, and Auriga, Brorsen-Metcalf reached 7th magnitude by mid-August and was viewed and photographed by hundreds of backyard astronomers.

"Comet Brorsen-Metcalf is subtle," said Martin Hale of Simi Valley, California. "When I located it on July 16, I was surprised that it was invisible in my 4-inch guidescope until after the Moon set and the sky was *really* dark." Hale reported that the comet "suddenly popped out, a large, amorphous smudge of light with no central condensation or nucleus." Hale photographed the comet on July 16 and produced a pseudo-stereoscopic pair by shooting two exposures of the comet timed a few minutes apart. "I did not see a tail or record one on the negatives, but after making three successive generations of duplicates I noticed what appeared to be a faint, thin ion tail," remarked Hale. "However, I don't think this tail would have been visible in amateur telescopes." Stay tuned for the further adventures of Comet Brorsen-Metcalf.

ASTROPHOTOGRAPHY AT THE TEXAS STAR PARTY

Observers of stars and planets had a rough time at this year's Texas Star Party. Normally arid Fort Davis in the Davis Mountains of western Texas got socked nightly with rains. However, the inability to see stars at night didn't stop astrophotographer Trey Mitchell of Palm Coast, Florida.

"Why not take advantage of the celestial objects that *are* within reach?" Mitchell reasoned. "After a couple of cloudy nights I began shooting the Sun,

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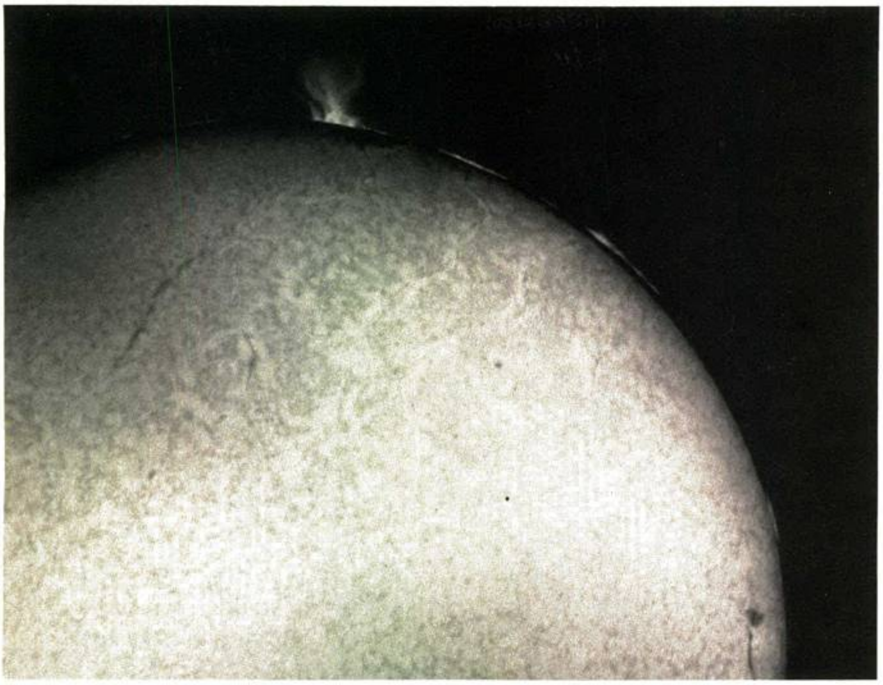

A SOLAR PROMINENCE rises above the Sun's chromosphere on May 1, 1989. Trey Mitchell used a 10-inch f/10 SCT, a Daystar Hα filter, Tech Pan film, and a 1/125-second exposure.

which was visible in a clear or slightly hazy daytime sky.

"I had fun taking astrophotos at last year's TSP," said Mitchell, "except that I didn't like waiting until I got home to see the results. Therefore, I brought all the darkroom gear I needed to develop and print photos, set it up in my room on the ranch, and had the capability to quickly develop and print any photos I took.

"My roommate Larry Mitchell had a 10-inch f/10 SCT set up for hydrogen-alpha solar photography. I chose Tech Pan film in order to capture as much prominence and sunspot detail as possible. The key was shooting lots of film. Seeing varied considerably, and I got several slightly fuzzy frames for each sharp one. I did manage to get one very sharp frame that recorded a large prominence and good sunspot detail. Making the print, I burned in the disk of the Sun heavily to let both surface and prominence show well.

"Whether you're viewing under a black sky, photographing through holes in clouds, or shooting the Sun, enjoying the universe that you can see is what it's all about." — *David Eicher* ☐

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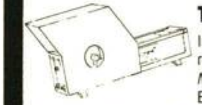

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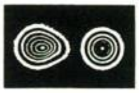

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DOING SCIENCE WITH THE SOVIETS

In April 1989, two graduate students studying planetary science at the California Institute of Technology journeyed to the Soviet Union with Bruce Murray, a leading American planetary scientist. During their week-long stay, they worked with Soviet scientists on the results of the *Phobos* mission (see "New Views of Mars and Phobos" by Robert Burnham, September 1989).

Unlike other fields of astronomical research, planetary science depends critically on fresh data gathered by automated probes. In light of this, both students had different responses to and drew different conclusions about the premature demise of *Phobos*. Bruce Betts, twenty-two, noted that it forced him to change subjects for his thesis, and he sounded leery of becoming too dependent on any single mission, or even a particular planet. "My career isn't tied to Mars," he said. He commented further that his career would "follow the data."

On the other hand, Michelle Santee, twenty-nine, was already deeply engaged in Mars research. "For several years I've been fashioning myself more or less to be a Martian," she said. For her, the results of the *Phobos* mission simply added new perspectives to the problems she was already studying.

Bruce Betts: Right now I'm most interested in using visible and infrared instruments to study the surface properties of Mars. My original intent was to use *Phobos* data to investigate how water ice clouds form in some of the equatorial regions of Mars where water appears to be condensing on the surface and evaporating after local sunrise. That plan was thwarted by the failure of the spacecraft because the instruments didn't take the data I needed before the mission ended.

I'm now going to have to reorient my research to fit the data that actually was taken. I'll be correlating the data from *Phobos*' TERMOSKAN infrared imager with data taken by *Viking* to assess the amount of water at or right below the surface. I'll also be comparing different areas on Mars that heat up rapidly after sunrise and cool down quickly after sunset.

I've just started to work on this, so it's too early to say how it's going to come out, but I'm excited about the quality of data *Phobos* collected. I and a couple of others here at Caltech will be working independently of the Soviets on the data and we'll compare our results with theirs.

You know, this whole experience has been fascinating — and for a graduate student, an almost unique opportunity. The science has been certainly interesting, but there's more than that, of course, because visiting Soviet society is overwhelming. You read in the newspapers about the cultural differences, but when you go there, they just knock you over.

The Soviets lack so many things that we take for granted. For instance — to cut right to the heart of it — toilet paper. Theirs is terrible. That's rude to say, but it's very noticable when you're there.

And the food — well, you've read about the shortages. They're very real, and what food there was produced some of my least favorite experiences. Luckily, I'd been to the Soviet Union once before, so I knew what to expect and I took a lot of food with me. We usually ate breakfast and dinner at the hotel, and lunch was at IKI, the home institution for most of the scientists on the project. [IKI is the Institute for Space Research, known to scientists East and West alike by its Russian acronym.] I couldn't find much I wanted to eat anywhere. At IKI, for instance, you go through a cafeteria line, but there's no choice. You get what there is, that's it.

To get back to the subject of the mission, I found the Soviet scientists very friendly to work with, although we spent a lot of time hammering out details of the data-sharing agreements. You could see a lot of frustration among their scientists, mostly directed toward the engineers, who seemed unwilling to admit that the spacecraft's problems had come from their side. *Phobos* was the first completely new design of spacecraft in twenty years and it's meant to be a workhorse for the future. But many scientists felt that the engineers weren't very interested in fixing the spacecraft — and it struck me that there was much less communication between scientists and engineers than you'd get here at JPL, for example.

Michelle Santee: My research interest is heat flow in the Martian atmosphere, and I've been working primarily with data from *Mariner 9*. Initially, the *Phobos* data didn't appear of much direct use. But when I looked more closely at what was received, I thought it could be useful so I was very excited to get the chance to go to Moscow.

Before we left, there was an attitude around Caltech that there wasn't going to be much data. When we returned people asked us, "Did you really get anything or did you just sit around and look at old *Viking* pictures?" It turned out that the Soviets got a lot less than what the mission was designed for, but the data that did come out was very valuable.

We now have agreements with the Soviets to exchange data. Seeing Dr. Murray in action was impressive; he's very effective with that kind of scientific diplomacy. We signed protocols and agreements and worked out several accords for sharing data with Soviet scientists and engineers. I was impressed to see how much science got done in hallways — not while sitting in the general assemblies for formal presentations. ("Hey, Sasha. What do *you* think happened to the spacecraft? D'you think a meteorite hit it?" "Of course not!")

The Soviets were very open in our talks. I spoke with Dr. Krasnopolsky, the principal investigator for the infrared part of the AUGUST experiment, which had relevance to what I'm working on. He was extremely helpful. He was willing to sit down with me and tell all about his data. He showed me rough graphs he'd done by hand and said, "This is all there is yet!" When I later asked him for a preprint of his forthcoming paper, he said, "Well, I'll try. If I can at all, I will."

While the Soviets were open and forthright, working out agreements with them was very time-consuming and patience-testing. We finally arrived at agreements to exchange data, but they argued incessantly over every single word. It was difficult and slow because we were working through an interpreter, and everything had to be fully discussed and understood.

I was intrigued to see that the reaction by the Soviets to the mission's failure split sharply along institutional lines. The response of IKI's scientists was very different from that of the engineers from the Babakin Research and Testing Center, who built the craft.

My impression was that the people at IKI felt something went wrong with the internal systems of the spacecraft. The people from Babakin, however, were promulgating the "act of God" theory: that it was either a hit by a micrometeorite or a solar flare. They tried to milk that one for all it was worth.

Before we went over, some Caltech people met with scientists from JPL to get their ideas on the failure. Tom Duxbury of JPL had reams and reams of data from *Viking* on the meteorite abundance at Mars from *Viking*'s four hundred or so passes through the orbit of Phobos. Nowhere did any debris show up. In short, we concluded impact was very

BRUCE MURRAY urged the Soviets to report openly on the causes of *Phobos*' failure.

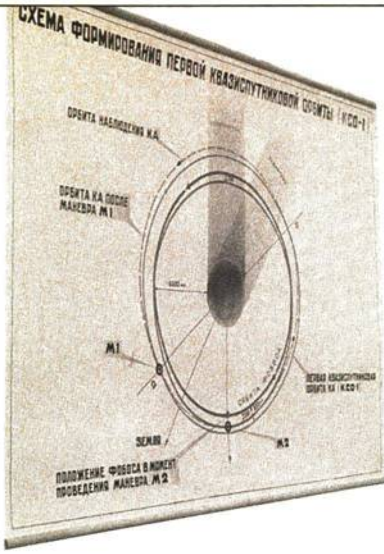
MICHELLE SANTEE keyed in the English version of the data-sharing agreements.

unlikely.

So we had this seminar one afternoon at IKI, saying "Guys, drop the micrometeorite idea. It just didn't happen." And everyone seemed in agreement. Then we got to the press conference, and they reviewed all the possible causes for the demise of the spacecraft, and prominent among them were micrometeorites and solar flares again!

As soon as the discussion was open to questions, Tom Duxbury asked if they had calculated the probability for the two theories. A Soviet scientist later said that he was too delicate — "not Soviet enough" — in his question.

The person who answered the question was from the Babakin Center. I'm not sure which engineer answered, but he should get a medal for illustrating Newspeak. This guy talked for fifteen minutes and didn't say *anything*. After which, Roald Sagdeev, the former head of IKI, reached over, grabbed the microphone, and growled into it, "Ten to minus five" — that is, one chance in a hundred thousand — and shoved the microphone away. It was a great moment.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ПЕРВАЯ КВАЗИСПУТНИКОВАЯ ОРБИТА КА (КСО-1)

THE VISITORS' CENTER at Glavkosmos was replete with colorful graphics.

Then Murray, who has worked for many years to increase research collaboration with the Soviets, stood up and delivered an impassioned speech, saying in effect, "Look, if you people don't drop this cover-up mentality and admit failure, you're going to have a very hard time convincing Americans and others to collaborate with you in the future."

At one point, because seating was scanty, I found myself literally sharing a seat with a scientist from Bulgaria. He tried to steal my chair and I stole it back and so we ended up sharing. When Murray had finished his appeal for openness, I turned to the Bulgarian and asked him if what we'd just heard was a good thing. He replied, "Oh, yes, yes. That was great. They really need to hear that."

I can understand the reluctance on the part of the Babakin engineers to talk about what happened, but they are facing a whole community of scientists who are not easily fooled.

One of my biggest shocks came when I went into the offices at IKI. These are scientists with world reputations — and they're sitting two and three together in little dingy offices that were nowhere near as nice as the offices graduate students in the United States get.

The same cannot be said of the main control center at Glavkosmos. [Glavkosmos coordinates all foreign dealings with the Soviet space industry.] That place was beautiful: chandeliers, parquet floors, gorgeous dining room. They told us we were in the room for the "Big Cheeses," and it was very much a show-and-tell sort of place. The conference room had soft chairs arranged around a set of TV monitors in a circle, obviously designed to impress visiting dignitaries.

The comparison with IKI was depressing. Here were these people at IKI trying to put missions together at tiny desks crowded into poorly lit rooms. Pieces of electronic equipment were lying everywhere: voltmeters, soldering irons, wire. It's all pretty hands-on there! *And practically no computers.* I was struck that they're trying to do the same work as we are, but they don't have our support base. I'm not saying their space program would benefit from nicer offices, but it indicates an attitude they probably have to fight against all the time. It made me wonder — is the "clean room" where they assemble the spacecraft like this, too?

I also saw evidence of a tremendous amount of feuding between separate institutes that are supposed to be working together, even reaching the point of strong personal dislikes between the leaders of the institutes. This is hard to talk about accurately because I spent most of the week just trying to understand who was who.

A case in point: the principal investigator on the TERMOSKAN instrument was Margarita Narayeva. She had worked on many instruments in the past — *Venera* missions and others — so she has a lot of experience. She works for Glavkosmos, where she and her group designed and built the TERMOSKAN instrument. Yet she did not have the data the instrument recorded and was unable to process it into meaningful results.

On the other hand, we did see some of the processed data and they were beautiful images. But they had been processed by the mission control center, which struck me as highly unorthodox, to say the least. I mean, mission control *flies* a mission. What were they doing reducing the data without the principal investigator being involved? There was some politics going on that I don't understand.

In general, the Soviets take a more haphazard approach to their experiments than we do. They just throw an instrument onto a mission and if it works, it works. If it doesn't — well, that's a result, too. While we will spend great sums testing everything thoroughly long before the flight, they were making major instrument alterations practically right up to launch.

You know, for all the central planning the Soviet Union is known for, they have very little of it in their space program. The lack creates gross inefficiencies, it prevents sharing data, and it plays too large of a role in determining what instruments get on a mission.

But in the end, I'd say this experience has been priceless. We and the Soviets are both studying the same solar system. It makes sense to coordinate the programs and dovetail our areas of investigation. I look forward to opportunites to work with them on their *Mars '94* mission. — *Robert Burnham* ☐

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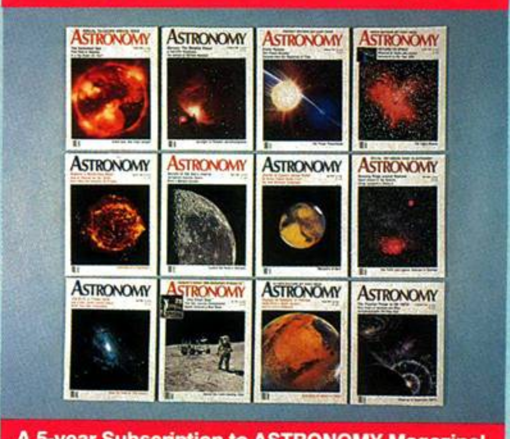

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OBSERVING GUIDE ATTEMPTS TOO MUCH

1000+: The Amateur Astronomer's Field Guide to Deep-Sky Observing by Tom Lorenzin with Tim Sechler, (1000+, P.O. Box 700-T, Davidson, NC 28036; 1987), ISBN 0-912081-06-6, softcover, 158 pages, $42.95.

This combination basic deep-sky observing guide, sky atlas, and database of over a thousand objects that can be seen in an 8-inch scope is intended for beginning amateurs. Although *1000+* fulfills that purpose for the most part, it is burdened by organizational problems and its attempt to serve as both an introduction to amateur astronomy and a detailed sky atlas.

Format-wise, *1000+* is 158 pages long and is wire-bound in a 15½ by 12-inch, dew-resistant softcover. Roughly half the book consists of introductory material, including sections on naked-eye, binocular, and telescopic observing; a guide to star hopping and using setting circles; telescope set up; and eyepiece and accessory descriptions. The introductory section concludes with a detailed readings and resources list and short appendixes on cleaning your optics and deep-sky sketching.

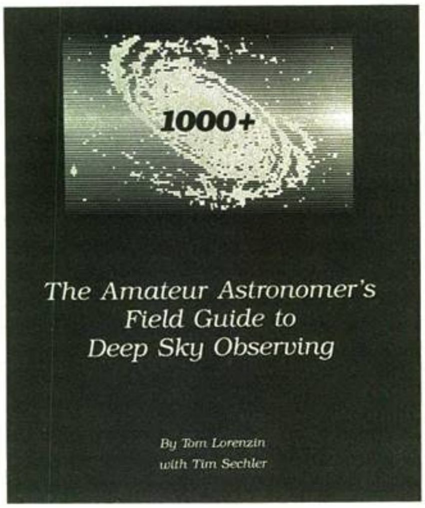
The second half is the "1000+ Database" itself — 1,200 deep-sky objects, double stars, and variables described in 1,055 separate entries. The last section is a sky atlas containing seven charts that show stars down to 6th magnitude; these charts include all of the objects in the database.

Looking at the introductory text as a whole, you can't deny that it provides a lot of basic information for the novice —from telescope fundamentals and accessory selection to polar alignment and astrophotography. But is it really practical to tote this information out to the observing site? Observers have enough to deal with already — telescopes, tools, flashlights, chairs, charts —without having to lug out a bulky book. Topics like telescope basics and eyepiece selection can be easily acquired from a number of sources, such as books, magazines, and astronomy clubs. I think *1000+* would have served the beginner's needs better *without* the introductory material. In the same respect, the introductory material, without the sky atlas, could have been expanded even more.

The writing is one of the strong suits of the introductory material: it is light, easy to read, and sometimes quite humorous. Beginners will find the sections on determining local sidereal time helpful for planning observing sessions, and there are good, common-sense discussions of accessories such as drive correctors, illuminated reticles, flashlights, and portable toilets.

The observing guide really shines in its use of graphics. The well-planned diagrams by Tim Sechler are very effective, particularly the meteor-radiant illustration. Detailed diagrams by Guy Ottewell on precession and the celestial sphere are also reproduced and are very helpful in explaining these concepts, reflecting Ottewell's usual high standards.

The second part of the book, the database, includes the best and brightest of all types of deep-sky and stellar objects. Each listing gives the object's coordinates, the object's catalog designation, object type (open cluster, galaxy, double star, variable star, etc.), its host constellation, and a brief description of the object.


1000+
The Amateur Astronomer's Field Guide to Deep Sky Observing
By Tom Lorenzin with Tim Sechler

The descriptions are organized in a thoughtfully consistent manner. Double stars, for example, always have details listed in this order: separation, position angle, magnitudes, and colors (or lack of colors). This lets you find key information quickly, especially when scanning for potential objects to observe. Similarly, variable-star listings give period, magnitude, color, and spectral type; deep-sky object listings always include magnitudes and angular diameters where relevant, followed by a description of the object's distinctive features.

The descriptions are surprisingly detailed, thanks to the large page format and a succinct, noncryptic syntax. There are a few shorthand descriptions — such as N-filter (nebular) and P-filter (light-pollution) — but these are adequately explained in the introduction preceding the database. All in all, the descriptions of the objects are accurate and reflect the author's first-hand experience.

For the beginner's purposes, however, the database section could be improved in three ways. First, each atlas chart should be numerically ordered. As they are now, the charts are distinguished by the central meridian overhead at certain times of the year. Numbering the charts would make way for the second improvement, which is to provide corresponding chart numbers for each object. This would facilitate going from the database to the atlas. Finally, brief astrophysical descriptions of some of the objects would add greatly to the information content. The emphasis, as with most deep-sky literature, falls on finding and looking at deep-sky objects. The descriptions rarely touch on the fascinating nature of these objects, something that greatly adds to the enjoyment of these faint, fuzzy things.

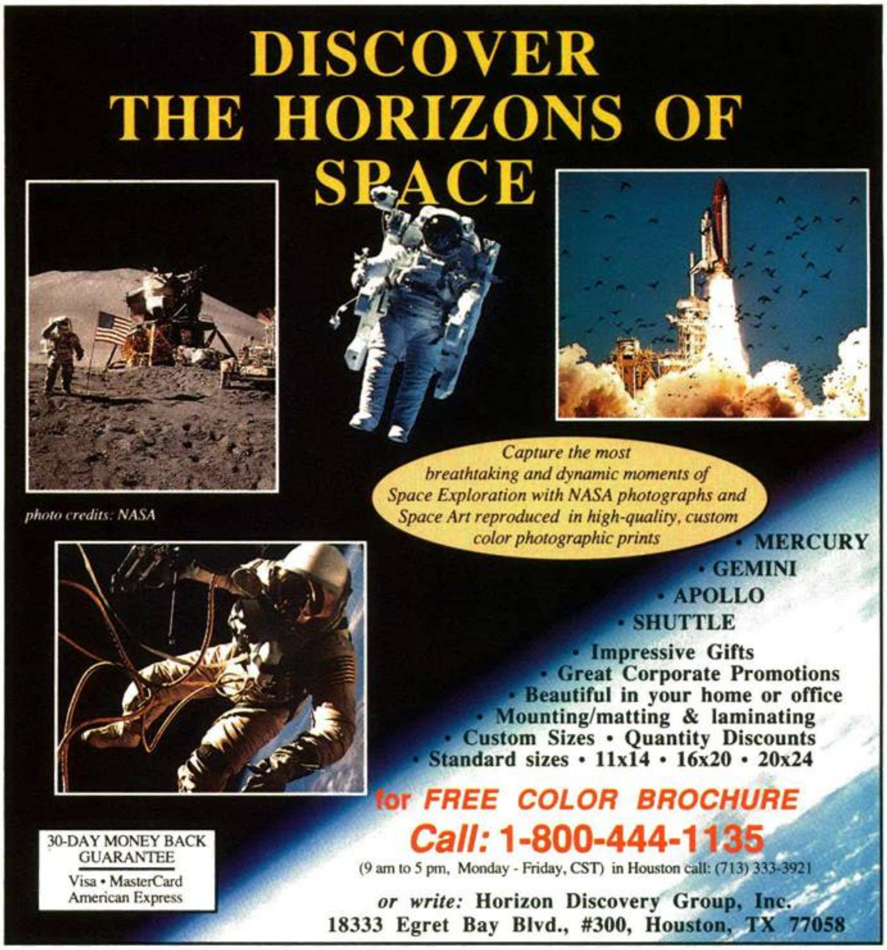
Aside from numbering the charts, one other improvement could have been made in the sky atlas: provide fainter stars for star hopping. Lorenzin says the atlas is complete to 6th magnitude, essentially making it a naked-eye star chart. But I would be surprised if a beginner could find some of the fainter objects listed in the database section using *only* naked-eye stars. For example, the atlas shows almost as many galaxies in Ursa Major as there are stars. If you use just the atlas, locating the fainter galaxies would require either good setting circles or pure luck in sweeping.

While it is an interesting idea to provide the beginner with a single source of both technical and observing information, this strength becomes a weakness when the observer has to carry extraneous information into the field every time he or she observes. *1000+* is a fine resource at the desk, but the sheer bulk of the text may prevent it from being used at the telescope as often as its authors would have liked. — *Robert Bunge*

BAJA ECLIPSE PAMPHLET

Baja 1991 by Paul J. Henry, (Paul J. Henry, 312 Lisa Ann Drive, Huron, OH 44839), softcover, 26 pages, $5.00.

This informative pamphlet contains all the relevant facts pertaining to the July 11, 1991, solar eclipse as seen from Baja California. It includes weather prospects, the eclipse track, eclipse phenomena, and a chart of the night skies over Baja. Available by mail order. ☐



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OBSERVERS' SOFTWARE

Astropoint II, (Dale C. Ferguson, 168 Edgewood Drive, Berea, OH 44017); for PCs, Apple II, and Atari computers, $19.95 (plus $1 shipping).

Astropoint II is a compiled BASIC program designed to help you plan an evening's observations or derive the past or future positions of celestial objects. Its output is numerical only, not graphic, but it has an accurate database that includes 1,700 stars and Messier objects, with stars complete down to magnitude 4.5.

Because the software is not copy-protected, COPY installs it on to a drive (single, dual, or hard). To start *Astropoint*, enter ASTR from the DOS directory. Once the program begins, you are asked for the terrestrial coordinates of your viewing site — and you're on your way.

Astropoint has both planning and observing modes. In planning mode, you enter the date, time, and an object's right ascension and declination. You then receive its precessed coordinates, hour angle, altitude above the horizon, and azimuth. These figures let you plan an observing session or compute the location of a particular object.

Calculations in the program are based on standard time, from which it calculates sidereal and universal times. When daylight-saving time is in effect, you make the correction by subtracting one hour from your input time. The program uses the present Gregorian calendar, so dates in the past based on the Julian calendar will be inaccurate by several days.

If you don't know the coordinates of the object you want, *Astropoint* can go into its database and attempt to locate the object for you. Simple prompts lead you to the object if it is in the database.

If you have a portable computer or an observing site close to your computer, you may find the observing mode is more valuable than the planning mode. Observing mode offers the opportunity of changing the date, time, or epoch. After you complete the inputs, the screen displays continually updated coordinates and tracking information.

Should any user be curious as to how *Astropoint II* operates, the author has provided the complete BASIC source code. Versions of *Astropoint II* have been prepared for the IBM PC, Apple II, and Atari computers. My tests were run using Insignia Software's Soft PC (a software-only IBM XT emulator) on an Apple Macintosh II. I found it returned new results from a calculation within seconds.

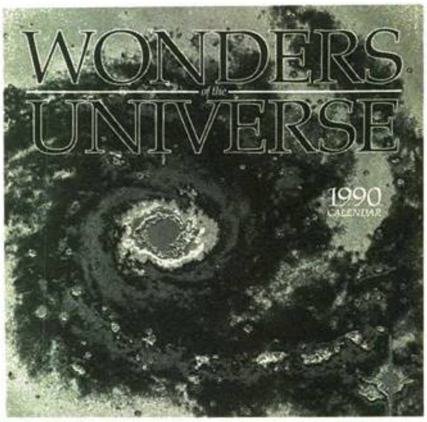
The sales literature for *Astropoint* calls it "The Poor Man's Computer-Aided-Telescope," but this is a little misleading because the program won't aim your scope. In its bare bones way, however, it provides the basic numbers you need to locate a given object.

Astropoint II's goal is simple: it is designed to help you point your telescope in the right direction. For $20 you'll find few programs that achieve this objective better. — *Daniel W. Rasmus*

1990 CALENDAR

Wonders of the Universe 1990, (Hansen Planetarium, 1098 South 200 West, Salt Lake City, UT 84101), no price given.

Wonders of the Universe 1990 is a wall calendar with twelve monthly images of mainly astronomical views. Among the images included are Earth from space, a satellite view of Europe, the false-color galaxy NGC 2997 (shown on the cover), parts of Valles Marineris on Mars, and noctilucent clouds over Alaska. The daily entries provide brief announcements of astronomical events. The page measures 11¼ inches square.



A COLORFUL UNIVERSE peeps out of the pages of the Hansen Planetarium's 1990 calendar.

ASTRONOMICAL BOARD GAME

Liftoff! by Fritz Bronner, (Task Force Games, 14922 Calvert Street, Van Nuys, CA 91411), no price given.

Liftoff! is a board game in which up to four players try to be first to land a crew of astronauts on the Moon. It is intended for ages twelve and up, and games last three to five hours.

Players begin in 1957 and proceed toward the goal by creating and running eight separate "programs" from launching an orbital satellite to carrying out the manned lunar landing. Each player collects funding (the smallest unit of currency is One Billion Megabucks!), buys new programs, bids for launches, and attempts missions.

ASTROPHOTO SOFTWARE

Better Exposure Times in Astrophotography, (DCD Software, P.O. Box 626, Horse Shoe, NC 28742); IBM PC, XT, AT, or compatible, $69.95.

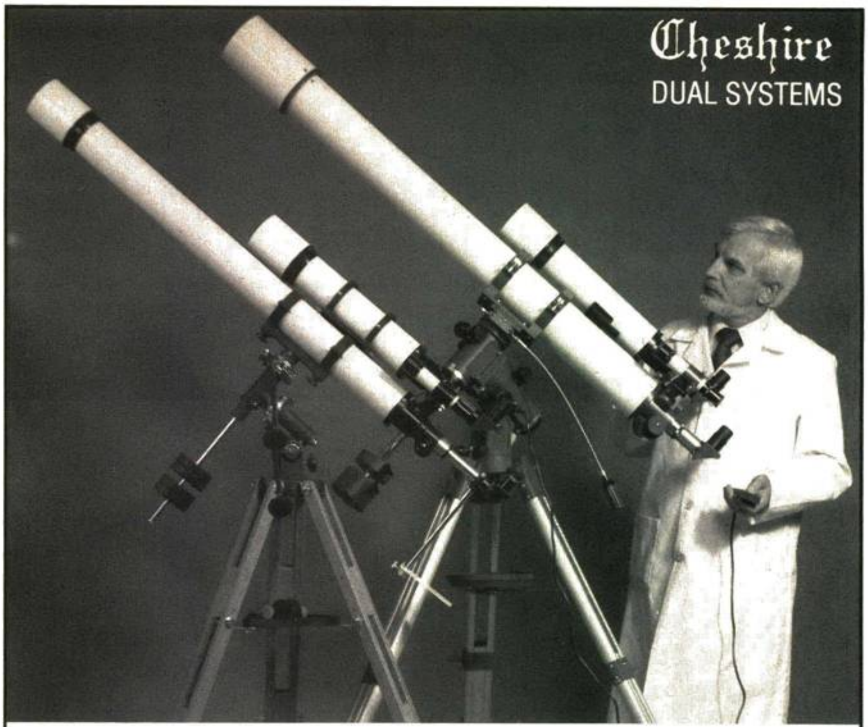
This program is designed to store information about your cameras, lenses, telescopes, eyepieces, and film. It then provides the best exposure time for a given celestial object. The program also makes provisions for filters and calculates the effective focal length and ratio for any optical arrangement (prime focus, afocal, eyepiece projection, or whatever). You can use the brightness values provided for objects or you can enter new values based on your photographic results.

The program needs 512K of RAM, at least one 360K floppy drive, and an 80-column monitor. It is not copy-protected, although you are allowed only to make backup copies.

UPDATES

The Binoc-U-Mount, a binocular holder (reviewed in March 1989), has been reissued in modified form at the same prices listed in the review. In our examination we found that the straps on the original model stretched too much to provide a secure grip on our binoculars when they were aimed upward. We examined a sample of the new design, which has straps with very little stretch and a larger Velcro patch. The mount now holds 10x50 binoculars securely no matter where in the sky they are aimed. The manufacturer, Innovative Energies, tells us that they will replace or modify copies of the older version returned to them free of charge.

Parsec Software, the publisher of *The Visible Universe* (reviewed in August 1989), informs us that the price of the professional version of the software has been reduced to $195. The standard version has been withdrawn and is being reworked into a student edition, which is not yet available. ☐



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Meetings and Events

October 18-21
25th Annual Great Lakes Planetarium Conference, Parkland College, Champaign, Illinois. Contact: David Linton, William S. Staerkel Planetarium, Parkland College, 2400 West Bradley Avenue, Champaign, IL 61821. Phone: (217) 351-2568.

October 26-29
Deep South Regional Stargaze, Percy Quin State Park, McComb, Mississippi. Sponsored by the Jackson Astronomical Association. Contact: Jeff Somers, 414 Woody Drive, Jackson, MS 39212. Phone: (601) 372-2275.

October 27-29
Astronomy Jamboree, Custer Institute, Southhold, New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, NY 11721. Phone: (516) 262-7807.

October 28-29
5th Annual Blue Ridge Parkway Regional Stargaze, Part Two, Julian Price Park, North Carolina. Sponsored by the Catawba Valley Astronomy Club. Contact: Greg Kirby, 12 East Street, Granite Falls, NC 28630. Phone: (704) 396-7656.

November 18-19
16th Annual Astronomical Association of Northern California Conference, Lawrence Hall of Science, Berkeley, California. Sponsored by the Astronomical Association of Northern California. Contact: Don Stone, 731 Camino Ricardo, Moraga, CA 94556. Phone: (415) 376-3007.

January 25-28
6th Annual Winter Star Party, Florida Keys. Sponsored by the Southern Cross Astronomical Society. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

Please submit announcements at least four months before the date of the meeting or event.

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ANNOUNCEMENT — The Ancient City Astronomy Club, Incorporated, meets every first Friday of every month at 8 p.m. in the First United Methodist Church, King Street, St. Augustine, Florida. Contact P.O. Box 546, St. Augustine, FL 32085-0546. Phone (904) 797-5704 or (904) 797-7110.

FOR SALE — 4.25" handmade telescope with Astrola equatorial mount (1.5" shafts), clock drive, 6" aluminum setting circles, zoom Ortho, 2x Barlow, pedestal-type base. Five other 4.25" parabolic mirrors, mounts, and ellipticals. $275 plus shipping. Contact Galen Smith, 629 Plantation Drive, Angleton, TX 77515. Phone (409) 848-0725.

FOR SALE — *Telescope Making.* #1, #2, #13, #14, #36. $5 each. *Planetary Astronomy.* $5. *NGC 2000.* $15. *Handbook of Natural Phenomenon* by William Corliss. $7.50. *UFO Prophecy* by Arthur Shuttlewood. $5. *UFO Review.* #3, #5, #14, #15, #16. $2 each. *Science Digest.* 1970s. $1 each. *Popular Science.* 1970-1971. $1 each. Orion eyepiece eyeguards 1-¼". $3.50 each. Contact Dan Isaac, Route 1, Box 626, Danville, WV 25053. Phone (304) 369-2216.

FOR SALE — 10" f/5-f/20 Newtonian-Cassegrain with 90mm guide scope and Schaefer mounting with quartz digital drive corrector. $3,800. Huge selection of accessories including Lumicon solar prominence filter. Will sell accessories separately or with scope for $4,500. 4" f/30 professional solar prominence telescope. Missing hydrogen-alpha filter. Great for active solar cycle. $250. Phone Jim at (415) 692-5337.

ANNOUNCEMENT — *Solar and Geomagnetic Activity,* a monthly newsletter of predictions, figures, diagrams, and analyses, is available. Contact Buryl Payne, 848 Walnut Avenue, Santa Cruz, CA 95060.

WANTED — *Telescope Making* #4, #17, and #30. Also, photos of backyard domed observatories, photos of 6" or larger refractors, and old astronomy books. Contact Steven Rigdon, 3541 South I-85, Charlotte, NC 28208.

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WANTED — Copy of *How to Build a Dobsonian Telescope*. Contact Michael Tshulos, 4828 Country Club Road, Binghamton, NY 13903.

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WANTED — Any information on Edmund Scientific Astroscan 2001. Contact Andrew McHugh, 311 North Rossevelt Avenue, Endicott, NY 13760.

FOR SALE — TeleVue Oracle 3″ refractor, mounted on Super Polaris tripod with Skysensor computer, 12-volt power supply, TeleVue 17mm Plossl, and foam-lined case. Never used. $1,250. Contact Russ Palmer, 10322 Scoville, Sunland, CA 91040. Phone (818) 353-8148 (evenings).

WANTED — Riverside Telescope Makers Conference proceedings from 1980-1982. Good condition. Will pay $10 each. Contact Rick Swenson, 610 North Walnut, Marshfield, WI 54449.

WANTED — Used telescope. Willing to pay $100 for a scope that is too small, obsolete, or in need of repair. Contact V. Brown, 680 South Beech Street, Manchester, NH 03103.

FOR SALE — Lumicon 58mm hydrogen-alpha pass filter. $28 plus $l postage. Contact L. Nelson, 503 Larch Drive, Petaluma, CA 94952. Phone (707) 763-8007.

FOR SALE — Celestron deluxe 2x Barlow 1-¼″ lens. Like new, used twice. $60 plus shipping. Contact Rick Finkbeiner, Springcreek Road, East Peoria, IL 61611. Phone (309) 699-3270.

FOR SALE — Meade tele-extender, Meade T-Adaptor, Celestron piggyback camera mount for C-8. $20 each, or all three for $55, postage included. Contact Maurice Schuh, Jr., 1235 50th Avenue North, St. Petersburg, FL 33703.

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FOR SALE — *Atlas Eclipticalis* (1958) and *Atlas Borealis* (1962). Both perfect. Both for $50. Contact Joe Anderer, Route 9, Box 327, Mountain Home, AR 72653. Phone (501) 492-6366.

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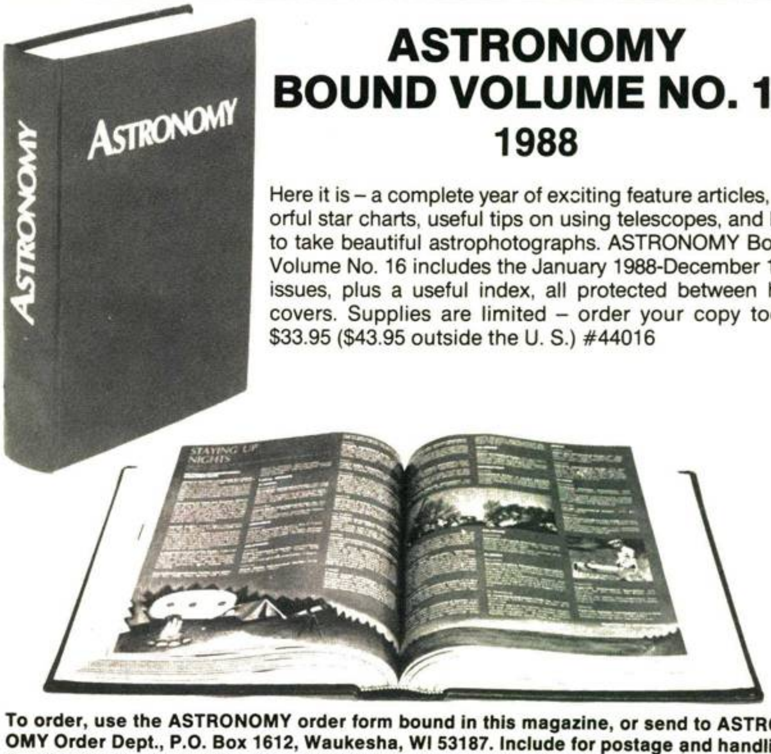

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Readings and Resources

The Hidden Milky Way (page 32)

The Milky Way by Bart J. Bok and Priscilla F. Bok, (Harvard University Press, 1981). Semipopular work on what astronomers know about the structure and evolution of our Galaxy.

"The Difficult Births of Sunlike Stars" by Steven Stahler and Neil Comins, ASTRONOMY, September 1988. This article discusses the conditions necessary for star birth.

Cross Section of the Universe (page 44)

Bubbles, Voids, and Bumps in Time: The New Cosmology, edited by James Cornell, (Cambridge University Press, 1989). Chapters by Robert Kirshner ("Measuring the Universe") and Margaret Geller ("Mapping the Universe") provide a good summary of the techniques and objectives in mapping large-scale structure.

Large-Scale Motions in the Universe, edited by Vera C. Rubin and George V. Coyne, S.J., (Princeton University Press, 1989). A technical but well-written compendium of scientific papers, including one by Margaret Geller and John P. Huchra on the status of redshift surveys.

Treasures of the Milky Way (page 76)

Burnham's Celestial Handbook by Robert Burnham, Jr., (Dover Publications, 1978). A massive, three-volume descriptive listing of deep-sky objects arranged by constellation.

Sky Catalogue 2000.0, Volume 2, edited by Alan Hirshfeld and Roger W. Sinnott, (Cambridge University Press and Sky Publishing, 1985). Lists fundamental data for thousands of deep-sky objects, including all bright objects in Perseus and Cassiopeia.

Joy of Color Printing (page 86)

Color Printing Techniques, Eastman Kodak Co. Covers how to make prints and slides using Kodak equipment and chemicals, though much of the information applies to other brands of processing kits.

"Working against the Grain of Fast Films" by Larry Myers, ASTRONOMY, February 1989. Describes the useful technique of printing several negatives of the same subject onto a single sheet of paper to reduce grain and enhance sharpness.

Supernova Hunter (page 94)

Supernova Search Charts and Handbook by Gregg D. Thompson and James T. Bryan, Jr., (Cambridge University Press, 1989). An atlas of 248 charts that enables amateur astronomers to search galaxies for possible supernovae. ☐

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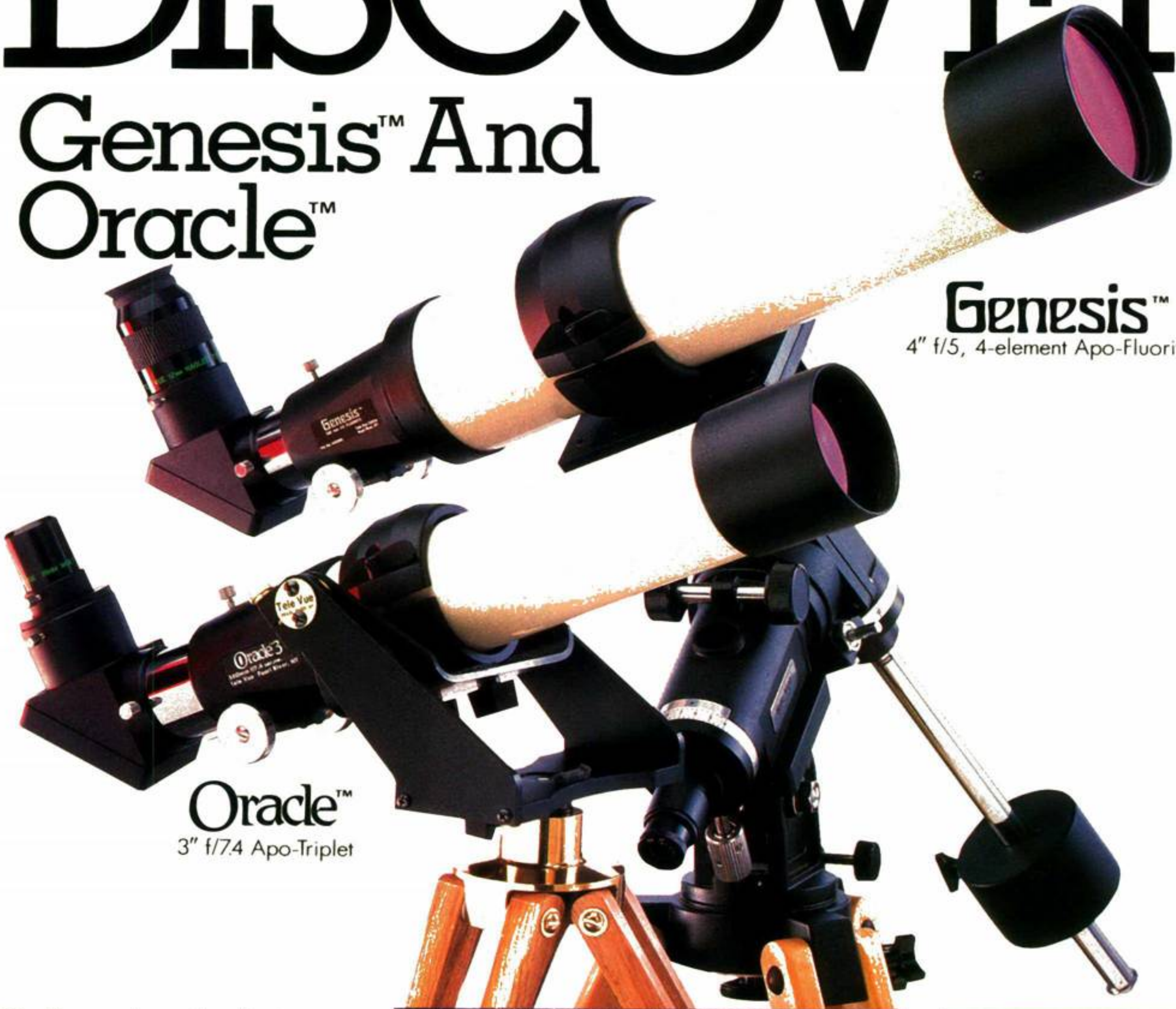

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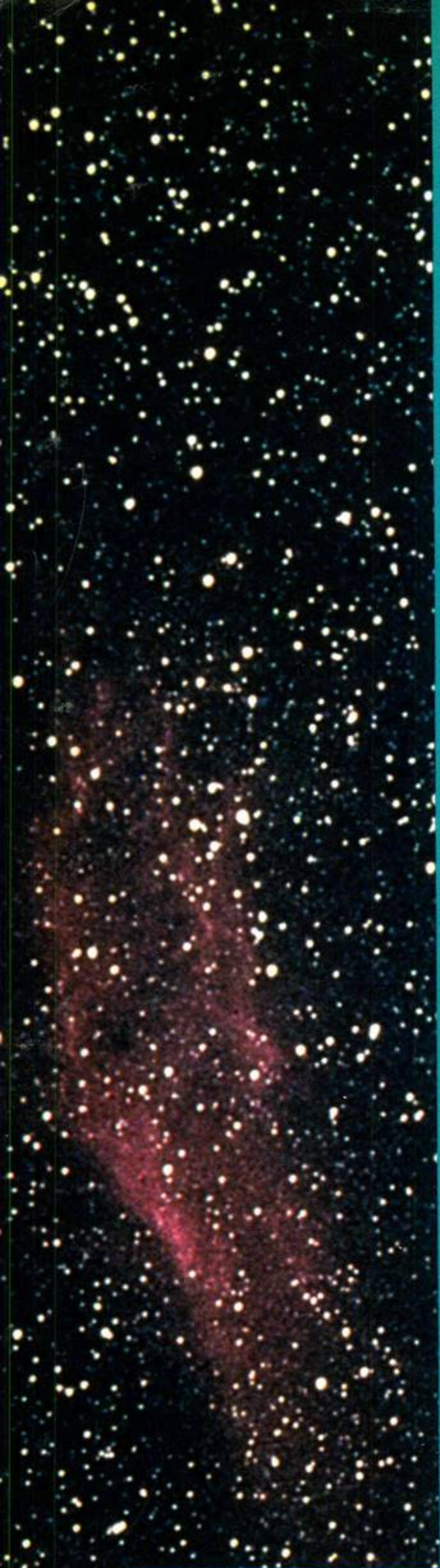

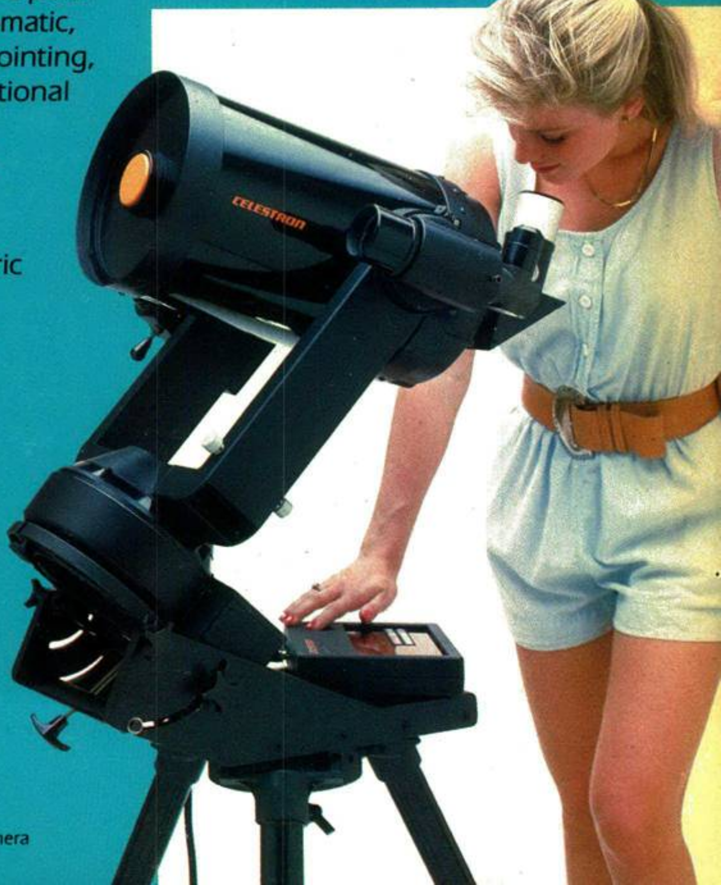

California Nebula, NGC1499, 8″ Schmidt Camera
Photo courtesy of Patrick McGuire